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GEORGE SINCLAIR

EDIT. 1672

SINCLAIR, George


G. SINCLARI
P. Professoris,
Hydrostatica
EDINBURGI,
Ann. Dom. 1672.
Intus se vasti Proteus tegit obice saxi.

THE HYDROSTATICKS;

OR,

The *Weight*, *Force*, and *Preſſure* of

FLUID BODIES,

Made evident by *Phyſical*, and *Senſible Experiments*.

TOGETHER

VVith ſome *Miſcellany Obſervations*, the laſt whereof is a ſhort *Hiſtory* of *Coal*, and of all the *Common*, and *Proper Accidents* thereof; a Subject never treated of before.

By *G. S.*

John Neilson
his book

EDINBURGH,
Printed by *George Swintoun*, *James Glen*, and *Thomas Brown*: Anno Dom. 1672.

To my very Honourable, and Noble LORD,

ROBERT
VISCOUNT of OXFUIRD,
LORD MACKGILL of COUSLAND, &c.

My Noble Lord,

THe first application I make, is for *pardon*, that I have adventured to prefix your *name* to the *Frontispice* of this Work, which in it self, cannot be thought worthy of your *Trust* and *Protection*; there being no proportion between the greatness of your *Merit*, and so mean an *Oblation*; save what flows from the Nobleness of the *Subject*, and the sincerity of his respects who presents it. It is truly a part of *Philosophy*, that was

never much Cultivated, but of late, except in a more abstract and subtil way, which did render it less useful; but is now more improven by sensible *Manifestations* of the Soveraign Mistriss of Arts, NATURE her self. There are indeed (my Lord) many excellent *Sciences*, which do merit the favour of your Lordships studies, and by which your Noble Accomplishments might be more improven; yet I am bold to affirm, you cannot apply your *Noble Mind* to any part of *Philosophy*, where you will find more Pleasure, with less Pains; more evidence of Reason, with less Difficulty.

The famous *Gregorio Leti*, was so much an admirer of your *Vertues*, that he sheltered under your *Patrociny*, his *Vita Di Sisto quinto Pontefece Romano*. And if you were able to protect an envyed *Italian* in *Italy*, much more may I expect full security from your Name in *Scotland*, where your interest and relations are so considerable. And if he, who only look'd upon your *Vertuous Mind*, while it was but blossoming, was so much perswaded to judge none

more

more fit to Receive, Protect, and Claim his *Labours*, much more *I*, who have seen the accomplishment of your *Vertues at home.* *I* have likewise very much confidence of your Noble and Candid Disposition to admit this into your *Favour*, and assurance of your Affection and Skill, to Love it, and Understand it; both which are conspicuous, the first in your encouragement to all *Learning*, the other in your Capacity and Understanding to comprehend, whatever you encourage.

Though (my Lord) I have been much emboldened to offer this *Dedication* to your Lordship, upon the account of your own *Heroick Vertues*, yet *I* must not pass over in silence, a most special Motive, which to me shall be the last, sparing to express all the great Causes oblieging me so to do, and that is, the Memory of your VVorthy and nearest *Relations*, who are, *my Lord your Father, Grand-father*, and *Great-Grand-father*, not only memorable for their Vertue and Learning, and peculiar Endowments, whereby they were

thought

thought worthy to ſerve their *King* and *Countrey*, in *Council*, and *Honourable Courts of Juſtice* for theſe many years, but for the *Dignity*, and *Antiquity* of their famous *Anceſtours*. How old your Lordſhips Name is, *Buchanan* teſtifies in the cloſe of the *Second Book* of his *Hiſtory*, who writeth thus, *Certè Gildus vetus eſt in Scotia Nomen, ut vetus Mackgildorum, ſive Mackgillorum gens indicat: è cujus poſteris honeſtæ adhuc in Scotia & Anglia ſunt familiæ.* That is, *Surely* Gild *is an ancient Name in* Scotland, *as witneſs the old Family of* Mackgilds, *or* Mackgills: *of whoſe Poſterity there are yet in* Scotland *and* England *many Families of good account.* And as an inſtance of this, the ſame Author tells us of the Great *Thane of* Galloway, *Mackgillum Gallovidiæ longè Potentiſsimum*, in the life of *Mackbeth*, who by this *Uſurper* was put to death for his adherence to his *Prince*, from whom your Lordſhip, and your worthy *Progenitors* are Lineally deſcended, and of whom *Buchanan* meant in the foregoing paſſage, ſince your Predeceſſors flouriſht in his time; your

Great-

Great-Grand-Father having then been His *Majesties Advocat*, his Brother *Lord Register.*

Having now (my Noble Lord) laid before you so many considerable Motives, which I humbly desire may prevail, I cannot but make my next *Application* for *Acceptance*, and seriously intreat this *Work* may be received into the Tuition of your *Favour*, and get a full *Protection* from the *Censorious*, and being enlightned with the splendor of your *Name*, and receiving the impression of your *Authority* upon it, may safely pass thorow the VVorld, for which singular Favour, I shall fervently wish to your Self and Noble *Family*, all Prosperity, and Happiness, and shall think my self very happy under the Character of,

My Noble Lord,

Edinburgh, May 20. (*the day of your Lo. Birth and Majority*) 1672.

Your Lo. most humble and much oblieged Servant,

GEORGE SINCLAR.

TO THE
READER.

Courteous Reader,

I *Shall not detain thee in the entry with a long* Preface, *but give a ſhort account of what is needful to be known, of the* Cauſe, Occaſion, *and* Matter *of the following Treatiſe. After the publication of my laſt* Piece, *about the* Weight *and* Preſſure *of the* Air, *I found it needful to treat of the* Preſſure *of the* Water, *becauſe of the near relation between the two: the operations, and effects of both depending almoſt upon the ſame* Principles *and* Cauſes. *And that there are many things, which cannot throughly be underſtood, of the* Preſſure *of the* Air, *without the knowledge of the* Preſſure *of the* Water: *therefore to make the firſt the more evident, I have ſpoken of the ſecond: the effects and operations of* Hydroſtatical Experiments, *being more conſpicuous and ſenſible, then the effects and operations of the other.*

The Occaſion *was ſome ſpare time I had now and then, for making ſome* Trials: *part whereof are publiſhed here; the reſt being rather ſome productions of Reaſon, attentively exerciſed on that Subject; which notwithſtanding may be called* Experiments, *though never actually tried, nor haply can be, becauſe of ſome accidental impediments: yet ſuppoſing they were, I make it evident, that ſuch and ſuch* Phenomena *would follow, whence many neceſſary concluſions are inferred.*

As for the ſubject matter, there are firſt, moe then thirty Theorems *in order to the* Preſſure *of* Fluid Bodies, *as* Air, Water, *and* Mercury, *which in effect are nothing elſe, but ſo many concluſions rationally deduced from various and diverſe effects of* Aeroſtatical, Hydroſtatical, *and* Hydrargyroſtatical Experiments, *which for the moſt part, I have tried my ſelf.*

There are next twenty Experiments *briefly deſcribed, by their own*

distinct Schematisms: *their* Phenomena, *according to the Laws of the* Hydrostaticks *are* salved, *and several new conclusions inferred. A* Proposal *is likewise made of a more convenient* Engine *for* Diving. *Here, several difficulties are proposed, and answered, and all the obvious* Phenomena *of* Diving *explicated. If the* Lead *which sinks the Ark, be judged too weighty, and big, which may render it not so tractable, and likewise hinder the* Ark *from going so near to the ground, as is desirable, and in some measure stop the sight, (which troubles are (I suppose) incident to the* Bell *also) it may be reduced to a far less weight, and quantity, and the overplus being made square and thin pieces, may line the mouth of the* Ark *without, between P Q and L M, according to the Figure 25, or may be put to, or taken away at pleasure. The* Bell *may have likewise in stead of this troublesome* Foot-board, *a weighty* Ring *of* Lead, *or two, to go round about the orifice without, in form of a* Girth, *or* Belt, *which may slip off and on at pleasure, and will as conveniently sink it, as if it had a weight appended: the* Foot-board *then may be of any form, quantity, or weight you please.*

There are thirdly some Miscellany Observations, *the design of which is only* Philosophical. *Some of them are* Experiments *made with the* Air-pump, *which I have adventured to insert here, even though the Noble* Mr. Boyl *hath given an account of many. But because the* Engine *was offered to me by the* Laird of Salton, *a Gentleman of a choise Spirit, I could not, but in obedience to his commands make use of it, and shew him the Product. There are also two or three Observations in the close, as that of the* Primum vivens *in* Animals: *of the* Aliment, and growth of plants: *and of the* motion of the Aliment in Trees. *To all which is added a short* History of Coal, *which I hope will be acceptable to some; this so needful a subject, never being treated of before by any. In it, mention is made of things common to* Coal *in general, as* Dipps, Risings, *and* Streeks. *Next, of* Gaes, *or* Dykes, *which prove so troublesome sometimes to the working of* Coal. *Thirdly, of* Damps, *and* Wild-fire. *Next, a method is taught for trying of Grounds, where never any* Coal *was discovered before. And lastly, the manner how* Levels, *or* Conduits *under-ground, ought to be carried on, for draining the* Coal, *and freeing it of Water.*

When this Book was first committed to the Preſs, *I ſent an* intimation *thereof to ſome of my friends, for their encouragment to it, a Practice now common, and commendable, which hath not wanted a conſiderable ſucceſs, as witneſs the reſpect of many worthy perſons, to whom I am oblidged. But there is a* Generation, *that rather, than they will encourage any new* Invention, *ſet themſelves by all means to detract from it, and the* Authors *of it: ſo grieved are they, that ought of this kind ſhould fall into the hands of any, but their own. And therefore, if the Author ſhall give but the title of* New *to his Invention, though never ſo deſervedly,* they fly preſently in his throat, like ſo many Wild-Catts, *ſtudying either to* Ridicule *his work altogether, a trade that uſually, the perſon of weakeſt abilities, and moſt empty heads, are better at, than learned men, like thoſe Schollars, who being nimble in putting tricks, and impoſtures upon their Condiſciples, were dolts, as to their Leſſon, or elſe fall upon it with ſuch ſnarling, and carping, as diſcover, neither ingenuity, nor ingenioufneſs, but a ſore ſickneſs, called* Envy.

In the Intimation, *I affirmed, that the Doctrine concerning the* Weight, *and* Preſſure *of the* Water *was* New. *This one word, like a ſpark of Fire falling accidentally among Powder, hath been the occaſion of ſo much debate. Their ground is, becauſe they look upon the* Hydroſtaticks, *as a* Science long ago perfected, *ſeing* Archimedes 2000 *years ago hath demonſtrat the* Water *to have a* Preſſure, *and ſome others ſince, as* Stevinus. *They affirm likewiſe, that all the* Theorems, *and* Experiments, *that are here, are either deduceable from* Archimedes, *and* Stevinus, *or are the ſame with theirs. If theſe Gentlemen had ſuſpended their judgment, till this Book had been publiſhed, I ſuſpect they would not have ſpoken ſo confidently. For* Archimedes *his propoſitions, they are but few, and proven (as* Mr Boyl *ſaith)* by no very eaſie demonſtrations, which have more of Geometrical ſubtility, than uſefulneſs in them. *But theſe, which are here propoſed, are not only uſeful, but evidently evicted by reaſon, and ſenſible Experiments, even to the meaneſt capacities. And though ſome of mine, may (perhaps) co-incide with ſome of his, which to me is but accidental, yet our way of procedour is* toto Cœlo *different. His way is more* Speculative: *this is more* Practical. *His demonſtrations*

are Geometrical *: these are* Physical. *His propositions are but for the* use of a few *: these are for the* use of all. *His are not illustrated, and confirmed by* Hydrostatical Experiments *: these are.*

Stevinus *a late Writer keeps that same method. Yet I judge it easie to let see, even in the entry, how little cogent some of his demonstrations are, without derogating from such a Learned Man. He hath indeed some* Pragmatical Examples *(as he calls them) for illustrating some of his* Geometrical Propositions, *anent the* Pressure *of the* Water; *but I leave them to be considered by the judicious and understanding. Again, in this* Method, *I am yet as much different from others, who have written lately, as from these I have been speaking of. For, I not only treat of the* Pressure *of the* Water, *but takes in with it, the* Pressure *of the* Air *joyntly ; since to explicat sufficiently the* Phenomena *of the* Hydrostaticks, *without it, it is impossible. And yet furder, I not only counterpoise* Air *with* Water, *but* Air *with* Mercury, *and* Water *with* Mercury, *by which means several mysteries, and secrets in this Art, are discovered.*

There are several Inventions found out of late in the Hydrostaticks, *whose events and effects, cannot be clearly deduced from the grounds of* Archimedes, *and* Stevinus, *who had not that clear discovery (for ought we know) of the* Pressure of the Air, *that some now have, without which, these effects can never be sufficiently explained. And who doubts, but others afterwards, may make farder discoveries, and profit the world yet more, with their Inventions, then any have yet done. Is then the* Hydrostaticks, a Science long ago perfected? *To this* Pedantick *Conceit, I must again oppose the judgment of* Mr. Boyl, *who saith moreover, that* the usefulness of this part of Philosophy hath been scarce known any farder than by name, even to the generality of learned men.

But let us suppose, that the notion *of the* Pressure *of the* Water, *is of an old date, even as old as the* Flood *(for* Noah *surely knew, that the* Pressure of the Water, *would sustain the* Ark) *and (giving, but not granting) that* Archimedes 2000 *years ago hath written all the* Principles of the Hydrostaticks, *doth this hinder any man now, from deducing* new Conclusions *from these* old Principles? *But there is here, no such thing, for neither in this nor in my last* Piece, *are my*

Adverſaries *able to* trace me. *'Tis like the purpoſes would have been ſo much the better, if I had followed other mens foot ſteps: and it is like they might have been ſo much the worſe. I doubt not, but I have lighted upon other mens thoughts in ſome things: and others writting on this ſame ſubject, who perhaps are my* Antipodes, *may fall upon mine. My* Antagoniſts *affirm, they are able to deduce all my* Theorems, *and the* events *of all my* Experiments *from the grounds of* Archimedes *and* Stevinus. *If* they take not their word again, *I hope they will do it; for now I put them to it. And though they ſhould, (which I am not affraid they ſhall do in haſte) yet they muſt prove next, that theſe* Theorems *and* Concluſions, *ſo deduced, are not* new, *which all their* Logick *will not prove. But what if we do more,* (ſay they) *even overthrow many of all your* Aeroſtatical *and* Hydroſtatical Experiments, *in this, and in your laſt* Peice? *I give you liberty, and for your hire, a* Guiny *for each* Theorem, *or* Experiment, *you are able to ranſack, in either of the two Books, though they come near to an hundred. But, ye muſt oblige your ſelves (*my Maſters*) to do it with* Reaſon, *laying aſide your* Sophiſtry *and* Canina eloquentia. *And this I offer, Reader, that I may reduce them, to a better* humour, *and encourage them to leave off* flyting, *and only uſe reaſon. Neither muſt they be like the* Waſp, *that only lights upon the* ſore place. *But if they love to kindle any more fire, they will find me proof againſt it. If it burn them, it ſhall not heat me. Neverthleſs, if they love to* juik *under deck,* like Green-horns, *having no courage in themſelves, or confidence in their cauſe, they muſt excuſe me, if at laſt, I write their names upon a Ticket, and bring them above deck. This is all I have to ſay, at preſent* (Reader) *and I bid thee farewell.*

ERRATA.

Pag. 22. lin. 8. *for* weight *read* benſil. Pag. 185. lin. 24. *for* E H, *read* F H. Pag. 235. lin. 24. *for* 500. *read* 5000. Pag. 307. lin. 26. read promoting. Pag. 313. lin. 22. *read* reflection. *Ibid.* lin. 25. *read* elaborarint. Pag. 317. lin. 2. *read* & magna.

Note, that in placing the Figures, the 12, that ſhould have the fourth place in the third Plate, hath the firſt place in the fourth.

Contents of the EXPERIMENTS.

Contents of the MISCELLANY OBSERVATIONS.

In Auctorem & Opus ENCOMIASTICON.

Ætheris expanſi, vitrei Maris Antitalanton,
Peroledos, Elaſin, *Fluidarum ritè videntes,*
Ingenio patefacta tuo, Magnalia rerum,
Laudarunt alacres Galli, Belgæque *ſagaces.*
Aggrederis nunc Arte Novâ, trutinare profundi
Corpora, ſubmerſas quondam producere Gazas,
Tollere demerſis ingentia pondera Cupis.
Gas *fracidum in* Cryptis *ortum Foſſoribus atrox,*
Submiſſo in Fundos Auræ renovante Flabello,
Propulſare doces, Lithanthracumque *Cavernæ*
Queîs foveantur Aquis, quo tendant, unde oriantur,
Ordine quò circum Saxorum ſtrata recumbant.
Quòd benè cœpiſti Naturæ cuncta foventis
Munera ſolerti perge Illuſtrare Matheſi.

GEORGIUS HEPBURNUS, *M. D.*
à Monachagro.

READER.

To the Reader.

Reader,

THat thou mayeſt know, by one word more, how uſeful this part of *Philoſophy* is, and how far from being a *Science long ago perfected*, take but this following *propoſal*, lately, ſince my Book came to a cloſe, communicated to me by a *Friend*, which, by his allowance, I have publiſhed, reſerving the Anſwer to himſelf, the Author thereof.

Brother,

BY *what you have publiſhed in your* Ars Nova & Magna, *and this* Book, *I have been led to this* Invention, *to beget within the Bowels of the Sea, a Power, or Force, which with great ſafety, and eaſe, ſhall bring up the greateſt weight, that can be ſunk therein:* ad data quæcunque pondera demerſa, in Maris viſceribus Potentiam producere, quæ modo ſecuro, & facili, è fundo cujuſvis altitudinis ad ſummum, ipſa evehat. *I drew a Letter one night, ſhewing the way how this might be done, which I communicated to you, that it might have been Printed with your* Book: *but after ſecond thoughts, I judged it more meet to keep it up for a time, and that it ſhould be ſet forth by way of* Propoſal *only at the firſt, by*

Ormiſton, Your Brother,
May 20. 1682. Mr. *John Sinclar*.

This *New Invention*, though Hydroſtatical, is truly Mechanical, there being here a *Pondus* and a *Potentia*, whoſe operations depends upon Mechanical Principles. But in

ſeveral reſpects it is far more admirable, than the moſt part of the Mechanical Engines, which are look'd upon as ſtupendious. Many things, almoſt incredible, are reported of *Archimedes*, which he admirably brought about, by his Mechanical *Powers*; but I am confident, that by this *Invention*, as great a weight may be lifted, if not greater, as the *Power* of any Mechanical Faculty can be able to move. I know, the greateſt conceivable weight, may be demonſtrat, to be moved by the leaſt conceivable Power, as the *Earth*, by the *force of a mans hand*. But how is it poſſible to contrive Artificially, an Engine for that purpoſe, which will do that by *Art*, which the demonſtration makes evident by reaſon? It was thought a great enterprize, when *Pope Sixtus* the fifth, tranſported an *Obelisk*, which had been long ſince dedicated to the memory of *Julius Ceſar*, from the left ſide of the *Vatican*, to a more eminent place, 100 foot diſtant; but to raiſe a Ship of 1000 Tun intirely, nay, a weight 100 times greater, is ſurely a far greater enterprize. This *Invention* is ſo much the more admirable, that not only by it, any ſuppoſed weight may be lifted, but from any deepneſs. Though this (perhaps) cannot be done Mechanically, becauſe of ſome *Phyſical*, or *Moral* impediment, yet according to the *Laws* of the *Hydroſtaticks* it can be demonſtrat, and made evident by reaſon. And if this be, then ſurely, when the *Weight* is determinat, as the burdens of all *Ships* are, and the deepneſs known to be within ſo many fathoms, this *Invention* cannot but be ſucceſsful.

Though the *ſtrength* of *Mechanical Inventions*, may be multiplied, beyond the bounds of our *Imagination*, whereby the greateſt *Weight*, may be moved, by the leaſt *Power*; yet the *Wiſdom* of *God*, hath thought it fit, ſo to confine that knowledge, that it cannot teach, how both

of

of them,can move with the ſame *quickneſs* and *ſpeed*. For, if that were, the very works of Nature might be overturned. Therefore, it is obſervable, that when a great *Weight* is moved by a ſmall *Power*, the motion of the one, is as much ſlower than the motion of the other, as the *Weight* of the one, exceeds the *Force* of the other. If it were poſſible *Mechanically* to move the *Earth* with the *Force* of a mans hand, the motion thereof would be as much ſlower, than the motion of the hand, as the *Weight* of the one, exceeds the *Force* of the other, which is a great diſadvantage. And as the *Weight* and *Power* do thus differ, as to *ſwiftneſs*, and *ſlowneſs* in motion, ſo alſo, as to *Space*. For, by how much the *Power* is in it ſelf leſs, than the *Weight*, by ſo much will the bounds or *Space*, the *Weight* moves thorow, be leſs than the *Space*, the *Power* goes thorow. If it were poſſible (keeping the ſame inſtance)to move the *Earth* with a mans hand, the *Space* thorow which it paſſeth, would differ as much from the *Space* the hand goes thorow, as the one exceeds the other; which is another diſadvantage.

It may be thought, that if this *Invention* depend upon *Mechanical Principles*, it may be obnoxious to theſe abatements. I anſwer, though there be in it a *Pondus*, and a *Potentia*, a *Weight*, and a *Power*; this moving the other, yet it will evidently appear from Experience, that the motion of the one, is as ſwift as the motion of the other, and that the one moves as much *Space* and bounds in the ſame time, as the other, which is a great advantage. In this, it excells all the *Mechanical Powers*, and *Faculties*, that have ever yet been invented and practiſed. If any think, that ſuch a device cannot be effectuat, without a conſiderable expence. I anſwer, the expence is ſo ſmall, that I am aſhamed to mention it. The method and manner of doing this, is moſt eaſie likewiſe. Neither ought this to be a ground, why any man

ſhould

should contemn it; since the most useful Inventions ordinarily are performed with the greatest facility.

As it commends this part of *Philosophy* to all ingenious *Spirits*, as most pleasant, and most profitable, so it gives a check to the *ignorant*, who look upon it as *a Science long ago perfected*.

In praise of the AUTHOR, and his WORK.

1.

WHilst Infant-Art no further did pretend
Then to flat notions, and a bare desire;
What by small toyl we now do comprehend,
Our Predecessors only did admire.

2.

Now fruitful Reason, arm'd with powerful Art,
Uncovers Nature to each knowing eye:
Our Author *to the World doth here impart*
What was before esteem'd a mystery.

3.

The various motions of that Element,
Whose liquid form gives birth to much debate;
By demonstration he doth represent,
Unfolding th' intrigues of that subtil state.

4.

The Waters Course, and Sourse, from whence they flow,
By him to th' sense so clearly are display'd:
Their current Weight, and Measure now we know,
'Tis no more secret, but an open Trade.

W. C.

HYDRO-

Hydroſtatical THEOREMS,

Containing ſome uſeful Principles in order to that excellent Doctrine, anent the wonderful *Weight*, *Force*, and *Preſſure* of the Water in its own Element.

THEOREM I.

In all Fluids, beſides the firſt and viſible Horizontal ſurface, there are many moe imaginary, *yet* real.

Figure 1.

FOR the better underſtanding the following Experiments, it is needful to premit the ſubſequent Theorems; the firſt whereof is, that in all Fluid bodies, ſuch as Air, Water, and Mercury, or any other liquid, there is beſides the firſt and viſible ſurface, innumerable moe imaginary, under that firſt, yet real, as may be ſeen from the following Schematiſm, which repreſents a Veſſel full of Water, where beſides the firſt ſurface

A B C D, there is a second E F G H, and a third I K L M, and so downward, till you come to the bottom. This holds true, not only in Water, but in Air also, or in any other Fluid body whatsoever. I call the under-surfaces imaginary, not because they are not real; for true and real effects are performed by them; but because they are not actually distinguished amongst themselves, but only by the Intellect.

THEOREM II.

In all Fluids, as it is needful to conceive Horizontal Plains, so it is needful to conceive Perpendicular Pillars, cutting these Plains at right Angles.

Figure 1.

THis Proposition is likewise needful for understanding the following Doctrine, anent the Pressure of the Water: for in it, as in all Fluids, though there be not Columes or Pillars actually divided, reaching from the top to the bottom, yet there are innumerable *imaginary*, which do as really produce effects by their pressure, as if they were actually distinguished. These *imaginary* Pillars are represented in the first Schematism, one whereof is A E I N O P Q, the other B F K R T, and so forth.

THEOREM III.

There is a twofold Ballance, one Natural, *another* Artificial.

BY the *Artificial Ballance*, I understand that which the Mechanicks call *Libra*, which Merchants commonly use. By the *Natural Ballance* (which for distinctions cause

I so

I ſo nominat) I mean, *v. g.* a *Siphon*, or crooked Pipe, wherein water naturally aſcends or deſcends, as high or low in the one Leg, as in the other, ſtill keeping an evenneſs, or likeneſs of weight.

THEOREM IV.

Fluid bodies counterpoiſe one another in the Ballance *of* Nature, *according to their* Altitude *only.*

THis Theorem will appear afterwards moſt evident, while we paſs through the ſeveral Experiments; and it is of ſpecial uſe for explicating ſundry difficulties that commonly occur in the *Hydroſtaticks*. The meaning of it is ſhortly this: while two Cylinders of Water are in the oppoſite Scales of the *Natural Ballance*, they do not counterpoiſe one another according to their thickneſs: for though the one Pillar of Water be ten times thicker, then the other, and conſequently heavier, yet is it not able to preſs up the other, that's more ſlender, and ſo lighter, beyond its own hight: and therefore they weigh only according to their *Altitudes*.

THEOREM V.

In all Fluids there is a Preſſure.

Figure 1.

THis is true not only of the Elements of Air, and Water, while they are out of their own place (as they ſpeak) but while they are in it. For Air and Water, being naturally indued with weight, the ſecond foot cannot

be under the firſt, unleſs it ſuſtain it: if this be, it muſt neceſſarily be preſt with its burden. So this Water being naturally a heavy body, the foot I cannot be under E, unleſs it ſuſtain it, and be preſt with the burden of it; the foot N, being burdened with them both. From this Preſſure, which is in Air, ariſeth a certain ſort of force, and power, which may be called *Benſil*, by vertue whereof, a little quantity of Air, can expand and ſpread out it ſelf, to a very large quantity, and may by extrinſick force be reduced to that ſmall quantity again. Though this expanſive faculty be evident in Air, yet it is ſcarcely diſcernable in Water, unleſs it be in very deep parts, near the bottom, where the Preſſure is great. This Preſſure is not of the ſame Degree in all the parts, but is increaſed and augmented, according to the deepneſs of the Air, and Water: for the Air upon the tops of Mountains, and high places, is thought to be of a leſs Preſſure, then in Valleys: and Water is of a leſs Preſſure, ten or twelve foot from the top, then twenty or thirty. So is the Water N, under a far leſs Preſſure, then the Water, P or Q.

THEOREM VI.

The preſſure of Fluids is on every ſide.

Figure 1.

THe meaning is, that Air and Water preſſeth not only downward, but upward, not to the right hand only, but to the left alſo, and every way. So the foot of water K, not only preſſeth down the foot R, but preſſeth up the foot F, yea preſſeth the foot I, and the foot L, with the ſame weight. And the firſt imaginary ſurface, is as much preſt

preſt up, by the water I K L M, as it is preſt down by the water E F G H. Upon this account it is, that when a Sphere, or Glob is ſuſpended in the midle of Water, or Air, all the points of their ſurfaces are uniformly preſt. After this manner, are our bodies preſt with the invironing Air, and the man that *dives*, with the ambient and invironing Water.

THEOREM VII.

All the parts of a Fluid in the ſame Horizontal Line, are equally *preſt.*

Figure 1.

THe meaning is, that the foot I, is no more preſt, then the foot K: neither is the foot L, more burdened, then the foot M. The reaſon is, becauſe each of theſe feet, ſuſtains the ſame weight: for E F G H are all of them, of the ſame burden: therefore all the parts of a Fluid in the ſame Horizontal ſurface, are preſt moſt equally. This holds true in Air, and Mercury, or in any other Liquid alſo.

THEOREM VIII.

The Preſſure of Fluids ſeem to be according to Arithmetical Progreſſion.

Figure 1.

THe meaning is, that if the firſt foot of Water, have one Degree of Preſſure in it, the ſecond muſt have only two; and the third muſt have only three, and ſo forth, which

which appears from the Schematiſm: for the firſt foot E, having one Degree of weight, and the ſecond foot I, having of its ſelf as much, and ſuſtaining E, it muſt have two Degrees, and no more. So the foot N, ſuſtaining two Degrees of Preſſure from I and E, muſt have the weight only of three Degrees, O of four, P of five. It's evident alſo from Experience, for while by the Preſſure of Water, Mercury is ſuſpended in a glaſs tub, we find, that as the firſt fourteen inches of Water, ſuſtains one inch of Mercury, ſo the ſecond fourteen inches ſuſtains but two, and the third, but three. But if the Preſſure were according to *Geometrical progreſsion*, the third foot of Water ought to ſuſtain four inches of Mercury, the fourth, eight; the fifth, ſixteen, *&c.* which is contrary to Experience.

THEOREM IX.

In all Fluids there is a twofold weight, one Senſible, *the other* Inſenſible.

THe firſt is common to all heavy bodies, which we find in Water, while we lift a Veſſel full of it from the ground. The *Inſenſible weight* of Water, and Air, or of any other Fluid, can ſcarcely be diſcerned by the ſenſes, though it be as real, as the former, becauſe the Preſſure is uniform. By vertue of the ſecond, bodies naturally lighter than Water, are driven from the bottom to the top, as *Cork*. So, a man falling into a deep Water, goes preſently to the bottom, and inſtantly comes up again. Here is a natural effect, which cannot want a natural cauſe; and this can be nothing elſe, but the Preſſure of the Water, by vertue whereof he comes up, and yet he finds nothing

thing driving him up, or pulling him up. Therefore, there is in all Fluid bodies, an *Insensible* weight, as there is one *Sensible*; seing the man that (perhaps) weighs seventeen Stone, is driven up fifteen or sixteen fathom by it. And it must be very considerable, and exceed the weight of the man, seing it is able to overcome such a weight. So are vapours and smoke driven upward by the *Insensible weight* of the Air, and by that same weight, do the Clouds swim above us.

THEOREM X.

The Insensible weight of Fluids, is only found by sense, when the Pressure is not uniform.

FOr understanding of this Proposition, I must suppose somethings that are possible, but not practicable. Put the case then, while a man opens his hand, the Air below were removed, he would scarce be able to sustain the weight of the Air, that rests upon the Palm above: or if the Air above were annihilated, he would not be able to bear down the weight that presseth upward. Or, while a *Diver* is in the bottom of the Sea, if it were possible to free any one part of his body from the Pressure of the Water, suppose his right arm, I doubt not, but the blood would spring out in abundance from his finger-ends: for the arm being free, and the other parts extreamly prest, the blood of necessity must be driven from the shoulder downward, with force, which cannot be without considerable pain. It is evident also, from the application of the *Cuppin-glass*, which being duely applied to a mans skin, causeth the Air to press unequally, the parts with-

out,

out, being more preſt, than the parts within, in which caſe the unequal Preſſure cauſeth the pain, and ſo is found by ſenſe.

THEOREM XI.

A Cylinder of Water, or of any other Fluid body, loſeth of its weight, according to its reclination from a Perpendicular *poſition, towards an* Horizontal *or levell ſcituation.*

FOr underſtanding of this, conſider that while a Pipe full of Water ſtands perpendicular, the loweſt foot ſuſtains the whole weight of the Water above it: but no ſooner you begin to recline the Pipe from that Poſition, but aſſoon the Preſſure upon the loweſt foot grows leſs; So that if the loweſt foot, in a perpendicular poſition, ſuſtained the burden of ten feet, it cannot ſuſtain above five or ſix, when it is half reclined. A certain evidence whereof is this, the more a Cyilnder of Water is reclined towards the Horizon, or Level, it takes the ſhorter Cylinder of Water to counterpoiſe it, as is evident in *Siphons*. For, though the one Leg, be ſixteen inches long, and the other but ſix; yet a Cylinder of Water ſix inches long, will counterpoiſe a Cylinder of ſixteen. But this cannot be, unleſs an alteration be made in the Preſſure. For, how is it poſſible, that a Cylinder of Water can ſometimes be in *æquilibrio* with a leſſer, and ſometimes with a greater weight, unleſs the Weight, and Preſſure of it, be ſometimes more, and ſometimes leſs? When I ſay a Cylinder of Water loſeth of its weight by reclination, it is to be underſtood only of the *Inſenſible Weight:* for the

the *Sensible Weight* is unchangeable, seing it is alwayes a Pillar of so many inches, or feet. Now the true reason, why the Pressure upon the lowest foot grows less, is this; the more the Pipe is reclined, the more weight of the Cylinder rests upon the sides of the Pipe within; by which means, the lowest foot is eased of the burthen, and is altogether eased, when once the Pipe lyes Horizontal.

THEOREM XII.

All motion in Fluids, is from the unequal Pressure of the Horizontal surface.

Figure 1.

FOr understanding this, I must distinguish a twofold motion in Fluids; one *common*, another *proper*, by vertue of the first, they incline, as all other heavy bodies, to be at the center of the Earth. It is evident in the motion of Rivers, which descend from the higher places to the valleys, even by vertue of that tendency they have to be at the *center*. By vertue of the second, they incline to move every way; not only downward, but upward, hither and thither. This sort of motion is peculiar, and proper only to Fluids; and it is that which is spoken of in this Theorem. I say then, that all motion in Fluids, is from the unequal Pressure of the Horizontal surface. For put the case A, were more prest then B, *e.g.* with a stone, then surely as the part A descends, the other part B will ascend, and so will C and D rise higher too. Suppose next, the part A were fred of the Pressure of the Air, then surely in the same instant of time, would the part A ascend, and the parts B C D descend. As this Proposition is true in order

to the first and visible surface A B C D; so it is true in order to the *imaginary* surface I K L M; for put the case the space I, were filled with a body naturally heavier then Water, as lead or stone, then behoved that part of the surface to yeeld, it being more prest, then the part of the same surface K. Or if the space K were filled with a body naturally lighter then water, as Cork, then ought the water R to ascend, it being less prest, then the water N or S.

THEOREM XIII.

A body naturally heavier then Water, descends; and a body naturally lighter, ascends.

Figure 1.

FOr understanding of this, let us suppose the quadrat space E, to be filled with a piece of Lead or Iron. I say then it must go down to I; and the reason is, because the quadrat foot of Water I, is more pressed then the quadrat foot of Water K. To illustrat this, let us suppose that each quadrat foot of this Water weighs a pound, and that the heavy body existing in E, weighs two pound. If this be, the foot of Water I, must yeeld, seeing it is more prest then K: upon the same account must the Water N yeeld, and give way to the Stone, seeing it is more prest then R. For according to the twelfth Theorem, *There cannot be unequal Pressure upon a surface, unless motion follow.*

For understanding the second part, let us suppose the space R, to be filled with a piece of Cork, that is specifically or naturally lighter then Water. I say then, it must ascend to the top B; and the reason is, because the quadrat foot of Water K, is more prest upward, then the quadrat

quadrat foot of Watet I, or L is : but this cannot be in Fluid bodies, unless motion follow thereupon. I say, it is more prest up, because R being lighter then N, or S, it must press with greater force upon K, then S can do upon L, or N upon I. It is still to be remembred, *That Fluids presseth with as much strength upward, as downward,* according to the sixth Theorem ; and that an Horizontal surface doth as really suffer unequal Pressure from below, as from above.

THEOREM XIV.

Bodies naturally lighter then Water, swim upon the surface and top.

Figure 1.

THe reason of this Proposition must be taken from the nature of an *equipondium*, or equal weight. For without doubt, there is a counter-ballance between the Pressure of the Water, and the weight of the body that swims. To make this probable, let us suppose there were a piece of Timber in form of a Cube, six inches thick every way, without weight. In this case, the under-surface of that four-squar'd body, being applied to the surface of the Water A, would ly close upon it, as one plain Table lyes upon the face of another, without any pressure : and it being void of weight, the part of the surface A, would be no more burdened, then the next part B adjacent, whence no motion would follow. Here is no *equipondium*, or counter-ballance.

Secondly, let us suppose the said body to acquire two ounces of weight, then it follows, that it must subside, and sink two inches below the surface A B C D ; and that so

so far, till it come by vertue of its new acquired weighr, to a counter-ballance with the Pressure of rhe Water. Which Pressure is nothing else, but as much force or weight, as is equivalent to the weight of Water, that is thrust out of its own place, by the subsiding and sinking of that body, two inches.

Thirdly, let us suppose the same body to acquire other two ounces of weight, then must it subside other two inches. Lastly, let us suppose that it acquires six ounces of weight, then it follows that the whole body sinks, so far, I mean, till its upmost surface be in an *Horizontal line* with the surface of the Water A B C D. Here it swims also, because the weight of it becomes just the weight of so much Water, as it hath put out of its own place. I say, it must swim, because if the Water I, was able to sustain the Water E, which is put from its own place, surely it must be able to sustain that body also, that did thrust it from its own place, seing both are of the same weight, namely six ounces. In this case, the body immerged, and the water wherein it is drowned, become of the same weight *specifically*, seing bulk for bulk is of the same weight. To make this body *specifically*, or naturally heavier then Water, and consequently to sink to the bottom, nothing is required, but to suppose that it acquires one ounce more of weight; which done, it presently goes down, I, being more burdened then K. Note by the way, a twofold weight in heavy bodies, one *individual*, the other *specifick*, and that two bodies agreeing in *individual* weight, may differ in *specifick* weight. So a pound of Lead, and a pound of Cork, agree *individually*, because they are both 16. ounces: but they differ *specifically*, because the one is naturally heavier then the other.

THEO-

THEOREM XV.

No Body that flots above Water, even though its upper surface be level with the surface of the Water, can ever be made to swim between the top and the bottom.

Figure 1.

FOr clearing this Propoſition, let us ſuppoſe F to be a four-ſquare piece of Timber, of the ſame *ſpecifick* and natural weight with Water, and conſequently its upper ſurface to be level with the ſurface of the Water A B C D. I ſay then, if it be preſt down to R, it ſhall ariſe thence, and never reſt till it be where it was, namely in F. The reaſon ſeems to be this, becauſe the four-ſquar'd body of Water R, is really heavier, then the four-ſquar'd piece of Timber F. If this be true, it follows of neceſſity, that it muſt aſcend: for if the Timber exiſting in R, be lighter then the Water R, the Water T muſt be leſs preſt, then the Water O, or the Water V; whence (according to the twelfth Theorem) *motion muſt follow*. Again, if the Timber R, exiſting in the Water R, be lighter then the ſame Water is, then muſt the Water K, be more preſt up then the Water I, or L; whence yet, according to the ſame Theorem, *motion muſt follow*. If it be ſaid, that the Timber F, is of the ſame weight with the Water R, becauſe, it being equal in weight with the Water F, which it hath thruſt out of its own place, it muſt alſo be equal in weight to the Water R, ſeeing F and R being of the ſame dimenſions, are of the ſame weight. There is no way to anſwer this difficulty, unleſs I ſay the four-ſquar'd body of water R, is really and truly heavier then the four-ſquar'd body of Water F. The

reaſon

reaſon ſeems to be, becauſe the Water R, is under a greater Preſſure, then the Water F; and by vertue of this greater Preſſure, there are really *moe parts* of Water in it, then in F; therefore it muſt be heavier. Even as there are far moe parts of Air, in one cubick foot near the *Earth*, then in ſix or ſeven near the *Atmoſphere*. Hence it is, that a pint of Water taken from the bottom of the Sea, fourty fathom deep, will be heavier, I mean in a ballance, then a pint taken from the ſurface. Take notice, that when the veſſel is once full at the bottom, the orifice muſt be cloſely ſtopped, till it come to the top: otherwiſe the parts that are compreſſed at the bottom, namely by the weight of the ſuperiour parts, relaxes themſelves, before they come to the top.

THEOREM XVI.

It is not impoſsible for a body to be ſuſpended between the ſurface *and the* bottom.

Figure 1.

FOr underſtanding this, ſuppoſe F to be a four-ſquare piece of Timber, which though it will not reſt but at the ſurface, A B C D, yet may be made to go down of its own accord, and reſt at T, namely, by making it ſo much heavier, as the Water T is heavier then the Water F. To know this difference, which is not very practicable; the Cube of Water T, muſt be brought from its own place, under the ſame degree of Preſſure it hath, and put into the Scale of a Ballance, and weighed with the Cube of Water F, put into the other Scale. Now if the Water T, be half an ounce heavier, then the Water F, then to make the Timber F hing in T, it muſt be made half an ounce heavier. There ſeems to be reaſon for it alſo; for if a Cube

Cube of Timber resting in the space T, be just the weight of the Water T, the *imaginary* surface O T V, is no more prest, then if T were Water, and so it cannot go downward: neither can it go upward, seing the under part of the Water R, is no more prest up by the Timber T, then if the space T were filled with Water. If it be said, according to this reasoning, a Stone may be suspended in a deep Water, between the top and the bottom, which is absurd. I answer, such a thing may happen in a very deep Water: For put the case a Cube of Lead twelve inches every way, were to go down twelve thousand fathom, it is probable, it would be suspended before it came to the ground. For coming to an *imaginary* surface far down, where the Pressure is great, a Cube of Water twelve inches thick there, may be as heavy (even *specifically*) as the Cube of Lead is, though the Lead be ten times heavier *specifically*, then any foot of VVater at the top. If Water suffer compression of parts, by the superiour burden; it is more then probable, that the second foot of Water burdened with the first, hath moe parts in it, then are in the first, and the third moe, then in the second, and so forth; and consequently, that the second is heavier, then the first, and the third heavier, then the second. Now, if this be, why may not that foot of Water, that hath sixty thousand foot above it, by vertue of this burden, be so comprest, that in it may be as many parts, as may counter-ballance a Cube of Lead twelve inches every way? If then, that *imaginary* surface, that is sixty thousand foot deep, be able to sustain the said foot of VVater, which perhaps weighs twenty pound, why may it not likewise sustain the Lead, that is both of the same dimensions with it, and weight?

Hence

Hence it is, that the Clouds do ſwim in the Air, by vertue of a counter-ballance: And we ſee, which confirms this Doctrine, that the thinneſt and lighteſt are alwayes fartheſt up; and the thickeſt and blackeſt, are alwayes fartheſt down.

THEOREM XVII.

The lower the parts of a Fluid are, they are the heavier, though all of them be of equal quantity and dimenſions.

Figure 1.

THis follows from the former, which may appear a Paradox, yet it ſeems to be true: for though the Water Q at the bottom, be of the ſame dimenſions with the Water E at the top, yet it is really heavier, which happens (as I ſaid) from the ſuperiour Preſſure. It is clear alſo from this, namely the Cube of Timber E, which ſwims upon the ſurface, being thruſt down to Q, comes up to the top again, which could not be, unleſs the Water Q, were heavier then the Water E. I ſuppoſe the Water E, and the Timber E, to be exactly of the ſame *ſpecifick* weight, and conſequently the ſurface of the Timber, to ly Horizontal with B C D. Now the reaſon, why the Timber aſcends from Q to E, is no other then this, namely that the one Water is heavier then the other; for the under part of the Water P, being more preſt up with the Timber exiſting in Q, then with the Water Q it ſelf, it muſt yeeld and give way to the aſcent: for if the Cube of Timber exiſting in Q, were as heavy as the Water Q it ſelf, it would no more preſs upon P, or endeavour to be up, then the Water Q does.

THEO-

THEOREM XVIII.

A heavy body weighs leß in Water, then in Air.

Figure 1.

THis is eaſily proven from experience; for after you have weighed a ſtone in the Air, and finds it two pound, and an half, take it, and ſuſpend it by a threed knit to the ſcale of a ballance, and let it down into the Water, and you ſhall find it half a pound lighter. The queſtion then is, why doth it loſe half a pound of its weight? I anſwer, the ſtone becomes half a pound lighter, becauſe the ſurface of Water on which it reſts, ſuſtains half a pound of it: For put the caſe a ſtone were reſting in R, that weighed two pound and an half in the Air, it behoved to weigh but two pound in this Water, becauſe the Water T ſuſtains half a pound of it. For if this Water T be able to ſuſtain the Water R, that weighs half a pound, it muſt be alſo able to ſuſtain half a pound of the ſtone, ſeing half a pound of ſtone is no heavier, then half a pound of Water. Note, that when a heavy body is weighed in Water, it becomes ſo much lighter exactly, as is the weight of the Water it thruſts out of its own place.

THEOREM XIX.

A heavy body weighs leſs nigh the bottom *of the Water, then nigh the* top *thereof.*

Figure 1.

FOr clearing this propoſition, I muſt ſuppoſe from the 17. Theorem, that the lower the parts of Water

be, they are the heavier, though all of them be of equal dimensions. If then the loweſt foot Q be heavier, that is, have moe parts in it, then the foot N, it of neceſſity follows, that a ſtone ſuſpended in Q, muſt be lighter then while it is ſuſpended in N or I. Becauſe, if a ſtone be lighter in Water then in Air, as is ſaid, even by as much, as is the weight of the bulk of Water, that the bulk of the ſtone expells, then ſurely it muſt be lighter in the one, then in the other place; becauſe ſuſpended in Q, it expells moe parts of Water, then while it is ſuſpended in N or I. For example, let us ſuppoſe the Water N, to weigh eight ounces, and the Water Q to weigh nine, then muſt the ſtone ſuſpended in Q, weigh leſs by an ounce, then ſuſpended in N, ſeeing as much is deduced from the weight of the ſtone, as is the weight of the Water it expells: but ſo it is, that it thruſts nine ounces of Water out of its own place in Q, and but eight in N or I; therefore it muſt be one ounce lighter in the one place, then in the other. This may be tried, with a nice, and accurat ballance, which will bring us to the knowledge of this, namely how much the foot of Water Q is heavier, then the Water N or O.

THEOREM XX.

One part of a Fluid, cannot be under compreſsion, unleſs all the parts next adjacent, be under the ſame degree of Preſſure.

Figure 1.

THis propoſition may be proven by many inſtances: for when the Air of a *Wind-gun*, is reduced to leſs quantity by the Rammer, all the parts are moſt exactly of the ſame *Benſil.* So is it in a Bladder full of wind. It's true,

true, not only in order to this artificial Preſſure, but in order to the natural Preſſure, and *Benſil* of the Air likewiſe. For the Air within a parlour, hath all its parts, under the ſame degree of natural compreſſion: ſo is it with the parts of the Air, that are without, and immediatly under the weight of the *Atmoſphere.* Its evident alſo in the parts of Water: for the foot of Water R, cannot be under Preſſure, unleſs the Water S, and N, be under the ſame degree of it. Though this be true of Fluids, while all the parts lye in the ſame Horizontal ſurface, yet to ſpeak ſtrictly, it will not hold true of the parts ſcituated under divers ſurfaces; for without queſtion, the foot of VVater T, muſt be under four degrees of Preſſure, if the VVater R, be under three. And if the Air in the loweſt ſtory of a building, be under ſix degrees of *Benſil*, the Air in the higheſt ſtory muſt be under five. If a man would diſtinguiſh *Metaphyſically*, and ſubtilly, he will find a difference of this kind, not only between the firſt, and ſecond fathom of Air, neareſt to the Earth, but between the firſt, and ſecond foot; yea, between the firſt and ſecond inch, and leſs; much more in Water, as to ſenſe. However it be, yet the Theorem holds true; for we find no difference ſenſible, between the compreſſion of Air in this room; and the compreſſion of Air in the next room above it, no not with the *Baroſcope*, or *Torricellian Experiment*, that diſcerns ſuch differences accurately. I judge it likewiſe to be true, in order to the next adjacent parts of Fluids of different kinds; for while a ſurface of Mercury, is burdened with a Pillar of Water, or a ſurface of Water, with a Pillar of Air, whatever degree of weight and Preſſure, is in the loweſt parts of theſe Pillars, the ſame is communicated entirely, to the ſurfaces, that ſuſtains them. So then, there is as much

force and power, in the ſurface of any Water, as there is Weight and Preſſure, in the loweſt foot of any Pillar of Air, that reſts upon it: otherwiſe, the ſurface of Water would never be able to ſupport the ſaid Pillar: for a ſurface of ſix degrees of force, can never be able to ſuſtain a a Pillar of Air, of eight, or ten degrees of weight.

THEOREM XXI.

The Preſſure of Fluids, may be as much in the leaſt part, as in the whole.

Figure 14

THis Theorem may ſeem hard, yet it can be made maniſeſt, by many inſtances: for albeit the quantity of Air, that fills a Parlour, be little in reſpect of the whole Element, yet ſurely, there is as much Preſſure in it, as in the whole; becauſe Experience ſhews, that the *Mercurial Cylinder* in the *Baroſcope*, will be as well ſuſtained in a Chamber, as without, and under the whole *Atmoſphere* directly; which could not be, unleſs the ſmall portion of Air, that's in this Parlour, had as much Preſſure in it, as in the whole Element. Beſides this, it will be found in a far leſs quantity: for though the *Baroſcope* were incloſed, and impriſoned ſo cloſs, within a ſmall Veſſel, that the Air within, could have no communion with the Air without, yet the Preſſure of that very ſmall quantity, will ſuſtain 29. inches of Mercury, and this will come to paſs, even though the whole Element of Air were annihilated. This Propoſition is likewiſe evident in order to the Preſſure of the Water: for put the caſe, the *Baroſcope*, whoſe Mercurial Cylinder is 29. inches, by the Preſſure of the

Air;

Air; were sent down to the bottom of a Sea 34. foot deep, within a Vessel, as a Hogs-head, and there exactly inclosed, that the VVater within, could have no commerce with the VVater without, yet as well, after this shutting up, as before, other 29. inches would be sustained, by the Pressure of this imprisoned VVater, which proves evidently, that there is as much Pressure in one Hogs-head full of VVater, at the bottom of the Sea, as in the whole Element of VVater, above, or about: for an Element of VVater never so spacious, if it exceed not 34. foot in deepness, can sustain no more Mercury, then 29. inches by its Pressure. Yea, though the Vessel with the *Baroscope*, and imprisoned VVater in it, were brought above to the free Air, yet will the VVater retain the same Pressure, and will *de facto* sustain 29. inches of Mercury, provided the Vessel be kept close. It is therefore evident, that as much Pressure may be in one small quantity of VVater, as in the whole Element, or Ocean. 'Tis to be observed, that this Theorem is to be understood chiefly of the lower parts of Fluids; seing there cannot be so much Pressure in the VVater P, as in the VVater Q; for in effect, there is as much Pressure in the VVater Q, as is in the whole VVater above it, or about it. From this Theorem, we see evidently, that the Pressure, and *Bensil* of a Fluid, is not to be measured, according to its bulk, and quantity, seing there is as much *Bensil* in one foot, nay, in one inch of Air, as is in the whole Element, and as strong a Pressure in one foot of VVater, or less, as there is in the whole Ocean: therefore the greatest quantity of Air, hath not alwayes the greatest *Bensil*, neither the greatest quantity of VVater, the greatest Pressure. But this will appear more evident afterwards.

THEO-

THEOREM XXII.

The Pressure, and Bensil *of a Fluid, is a thing, really distinct from the* natural weight *of a Fluid.*

Figure 1.

THis may be easily conceived; for as in solid bodies, the *Bensil*, and *natural weight*, are two distinct things; so is it in Air, and Water, or in any other Fluid. The ~~weight~~ Bensil of a *Bow*, is one thing, and the *natural weight* of it, is another. The weight of the Spring of a *Watch*, and the *Bensil* of it, are two distinct things. The weight (perhaps) will not exceed two ounces: but the *Bensil* (may be) will be equivalent to two pound. Though these may illustrate, yet they do not convince: therefore I shall adduce a reason, and it's this. The *natural weight* of a Fluid is less, or more, as the quantity is less or more; but it is not so with the Pressure, because there may be as much Pressure in a small quantity, as in a great, as is evident from the last Theorem, therefore they may be different. The first part of the Argument is manifest, because there is more weight in a gallon of Water, then in a pint. A second reason is, because a Fluid may lose of its pressure, without losing of its weight. This is evident from the Schematism, for if you take away the four foot of Water E F G H, and consequently make the four Pillars shorter, the foot of Water Q becomes of less Pressure, but not of less Weight, seeing the quantity still remains the same: at least, the loss of weight is not comparable, to the loss of Pressure. I say, it becomes of less Pressure, because there is a less burden above it. Thirdly, the Pres-

sure

sure and *Bensil* may be intended, and made stronger, without any alteration in the weight: so is the *Bensil* of Air, within a Bladder, made stronger by heat, without any alteration, in the weight of it. Likewise, the Pressure of the foot of Water Q, may be made stronger, by making these four pillars higher, without any alteration, at least considerable, in the weight; for it still remains a foot of water, whatever be the hight of the pillars above it. Lastly, the weight of a Fluid is *essential* to it, but the Pressure is only *accidental*; because it is only generated, and begotten in the inferiour parts, by the weight of the superiour, which weight may be taken away.

THEOREM XXIII.

Though the Bensil of a Fluid, be not the same thing formally *with the weight, yet are they the same* effectively.

THis proposition is true in order to many other things, besides Fluids: for we see that the *Sun*, and *Fire*, are *formally* different, yet they may be the same *effectively*; because the same effects, that are done by the heat of the *Sun*, may be done by the heat of the *Fire*. So the same effects, that are produced by the *weight* of a Fluid, may be done by the Pressure, and *Bensill* of it. Thus, the Mercurial Cylinder in the *Torricellian Experiment*, may be either sustained by the *Bensil* of the Air, or the *weight* of it. By the *Bensil*, as when no more Air, is admitted to rest upon the stagnant Mercury, then three or four inches, the rest being secluded, by stopping the orifice of the Vessel. By the *weight* of it, as when an intire Pillar of Air, from the top of the Atmosphere, rests upon the face of the stagnant

Quick-

Quickſilver. It is alſo evident in a *Clock*; which may be made to move, either by a weight of Lead, or by the force, and power of a Steel *Spring*.

THEOREM XXIV.

The ſurfaces of Waters, are able to ſuſtain any weight whatſoever, provided that weight preſs equally, and uniformly.

Figure 1.

THis is evident, becauſe the imaginary ſurface of VVater O T V X, doth really ſupport the whole ſixteen Cubes of VVater above it, yea, though they were ſixteen thouſand. And the reaſon is, becauſe they preſs moſt equally, and uniformly. VVhat I affirm of the imaginary ſurface, the ſame I affirm, of the firſt and viſible. For let a plain body of lead, never ſo heavy, be laid upon the top of the VVater A B C D, yet will it ſupport it, and keep it from ſinking, provided it preſs uniformly all the parts of that ſurface. It is clear alſo, from the ſubſequent Theorem.

THEOREM XXV.

The ſurfaces of all Waters whatſoever, ſupport as much weight from the Air, as if they had the weight of thirty four foot of Water above them, or twenty nine inches of Quick-ſilver preſſing them.

THis Propoſition is evident from this, that the Preſſure of the Air, is able to raiſe above the ſurface of any Water, a Pillar of Water thirty four foot high. For, put

put the case there were a *Pump* fourty foot high, erected among stagnant Water, and a *Sucker* in it, for extracting the internal Air, a man will find, that the Water will climb up in it four and thirty foot; which *Phænomenon* could never happen, unless the surface of the stagnant Water, among which the end of the *Pump* is drowned, were as much prest with the Air, as if it had a burden of Water upon it thirty four foot high. The second part is also evident, because if a man drown the end of a long Pipe, in a Vessel with stagnant Quick-silver, and remove the Air that's within the Pipe by a *Sucker*, or more easily by the help of the *Air-pump*, he will find the Liquor to rise twenty nine inches, above the surface below, which thing could never come to pass, unless the Pressure of the Air, upon the surfaces of all Bodies, were equivalent to the Pressure and weight of twenty nine inches of Quick-silver.

THEOREM XXVI.

All Fluid Bodies have a sphere of Activity, to which they are able to press up themselves, or another Fluid, and no further, which is less or more, according to the altitude of that pressing Fluid.

Figure 2.

FOr understanding this Proposition, let us imagine G H C D to be a Vessel, in whose bottom, there are five inches of Mercury E F C D. Next, that above the stagnant Mercury, there are thirty four foot of Water resting, namely A B E F. Lastly, that upon the surface of the said Water, there is resting the Element of Air G H A B, whose top G H, I reckon to be about

ſix thouſand fathom above A B. Beſides theſe, let us imagine, that there are here three Pipes, open at both ends, the firſt whereof C A G, having it's lower orifice C, drowned among the ſtagnant Mercury E F C D, goeth ſo high, that theu pper orifice goeth above the top of the Air G H. The ſecond, whoſe lower orifice I, is only drowned among the Water A B E F, reaches to the top of the Air likewiſe. The third, whoſe open end K, is above the ſurface of the VVater A N B, and hanging in the open Air, goeth likewiſe above the Atmoſphere. Theſe things being ſuppoſed, we ſee that no Fluid can, by its own proper weight, preſs any part of it ſelf, higher then it's own ſurface, ſeing the ſtagnant Mercury E F C D, cannot preſs it ſelf within the Pipe C G, higher then E. Neither can the VVater A B E F, preſs it ſelf higher within the Pipe I L, then the point N. Laſtly, neither can the Air G H A B, preſs it ſelf within the Pipe K M, higher then M. But when one Fluid preſſeth upon another, as the VVater A B E F, upon the Mercury E F C D, then doth the ſaid Mercury aſcend higher than it's own ſurface, namely from E to O, which point is the higheſt, to which the thirty four foot of VVater A B E F, can raiſe the Mercury, which altitude, is twenty nine inches above the ſurface E I F. But if a ſecond Fluid be ſuperadded, as the whole Air G H A B, then muſt the Mercury, according to that new Preſſure, riſe by proportion; ſo riſes the Mercury from O to P, other twenty nine inches. By this ſame additional weight of Air, the Water riſes thirty four foot in the Pipe I L, namely from N to R. Now, I ſay, the outmoſt and higheſt point, to which the Element of Air G H A B can raiſe the Mercury, is from O to P; for by the Preſſure of the Water

ter

ter A B E F, it riſes from E to O. And the higheſt point, to which the ſaid Air can raiſe the VVater, is from N to R. The reaſons of theſe determinate altitudes, muſt be ſought for, from the altitudes of the incumbing and preſſing Fluids: for as theſe are leſs or more, ſo is the altitude of the Mercury, and of the VVater within the Pipes more or leſs. The hight therefore of the Mercury E O, is twenty nine inches, becauſe the deepneſs of the preſſing water A B E F is thirty four foot. And the hight of the VVater N R, is thirty four foot, becauſe the hight of the Air G H, above A B, is ſix thouſand fathom, or thereabout. And for the ſame reaſon, is the Mercury O P twenty nine inches.

THEOREM XXVII.

A lighter Fluid, is able to preſs with as great burden, as a heavier.

Figure 2.

THis Propoſition is true, not only of VVater in reſpect of Mercury, but of Air in reſpect of them both: for albeit Air be a thouſand times lighter then VVater, yet may it have as great a Preſſure with it, as VVater; as is evident from this ſecond Schematiſm, where by the Preſſure of the outward Air G H A B, twenty nine inches of Mercury O P are ſupported, as well as the twenty nine inches E O, by the Preſſure of the VVater A B E F. So doth the ſame Air, ſuſtain the thirty four foot of VVater N R, which are really as heavy, as the twenty nine inches of Mercury O P. Now, if the weight of the Atmoſphere, be equivalent to the

weight of thirty four foot of Water, or of twenty nine inches of Mercury, 'tis no wonder to see Water press with as great weight as Mercury; which is likewise clear from this same Figure, where by the Pressure of the Water A B E F, twenty nine inches of Mercury E O are suspended, as truly as the Mercury C E, within the lower end of the Pipe, is supported by the outward invironing Mercury. The reasons of these *Phenomena*, are taken from the altitudes of the pressing Fluids: for though a Body were never so light, yet multiplication of parts makes multiplication of weight; which multiplication of parts in Fluids, must be according to altitude: for multiplication of parts according to thickness and breadth will not do it. Observe here, that if as much Air, as fills the Tub between N and L, were put into the scale of a Ballance, it would exactly counterpoise the thirty four foot of Water N R, poured into the other scale. Item, that as much Water as will fill the Tub between E and A, is just the weight of the Mercury E O. Lastly, that as much Air as will fill the Pipe, between O and G, is just the weight of the Mercury O P.

THEOREM XXVIII.

The Pressure of Fluids, doth not diminish, while you subtract from their thickness, *but only, when you subtract from their* altitude.

Figure 1.

FOr understanding this, let us look upon the first Schematism, where there are four Pillars of Water. Now I say, though you cut off the three Columes of Water, upon the right side, yet there shall remain as much Pres-

sure,

ſure, in the quadrat foot of VVater Q, as was, while theſe were intire. But if you cut off from the top, the VVater E F G H, then preſently an alteration follows, not only in the loweſt parts, nigh to the bottom, but through all the intermediat parts: for not only the VVater Q loſeth a degree of its Preſſure, but the VVaters P and O ſuffer the ſame loſs. This Theorem holds true likewiſe in order to the Element of Air. For if by *Divine Providence*, the Air ſhould become leſs in Altitude, than it is; then ſurely, the *Benſil* of the ambient Air, that we breath in and out, ſhould be by proportion weakned alſo. And contrariwiſe, if the Altitude became more, then ſtronger ſhould the *Benſil* be here, with us, in the loweſt parts: both which would be hurtful to creatures, that live by breathing. For if the Altitude of the Air, were far more then it is, our bodies would be under a far greater Preſſure, which ſurely would be very hurtful. And upon the other hand, if the Altitude of the Air, were far leſs then it is, we ſhould be at a greater loſs; for then, by reaſon of the weak *Benſil*, we would breath indeed, but with great difficulty.

THEOREM XXIX.

A thicker Pillar of a Fluid, is not able to preſs up a ſlenderer, *unleſs there be an unequal Preſſure.*

Figure 3.

FOr underſtanding this, let us ſuppoſe this third Schematiſm to repreſent a veſſel with VVater in it, as high as A B, among which is thruſt down to the bottom, the Pipe G H, open at both ends. I ſay then, the two thicker

Pillars

Pillars of Air E A, and F B, pressing upon the surface of the VVater A B, are not able to press up the Water H I, or the slender Pillar of Air I G within the Pipe, the one higher then I, the other higher then G. If it be said, they are heavier, because they are thicker. I answer, they are truly heavier, for the Pillar of Air F B apart, will be thrice as heavy, as the slender Pillar of Air I G. But, if you reckon the Pillar of Air E A, upon the left hand, both together, will be six times heavier, then the Air I G: yet are they not able, either severally, or conjunctly, to press up the Water H I, higher then I, or the Air I G, higher then G. For solving this difficulty, I must say conform to the fourth Theorem, that Fluid Bodies, counterpoiseth one another, not according to their *thickness*, and *breadth*, but according to their *altitude* only: therefore, seing the slender Pillar of Air I G, is as high, as either F B, or E A, it cannot be prest up by them. For by vertue of this equal hight, all the three press equally and uniformly, upon the surface of Water A B; and therefore according to the twelfth Theorem, there can be no motion. But if so be, the Pillar F B, were higher then the Pillar I G, then surely would the Water H I, be prest up; for in such a case, there is an unequal Pressure. Or if the Pillar I G, were higher then the Pillar F B, then surely would the Water I H be prest down, there being again an unequal Pressure: the Water within the Pipe, being more burdened then the Water about the Pipe. In a word, there's no more difficulty here, then if the Pipe were taken away: in which case, there would be but one Pillar of Air, resting upon the surface of Water A B. If it be said, the Pipe being thrust down, makes of one Pillar, three distinct ones, and conse-

Fig. 1. *Pag. 1*

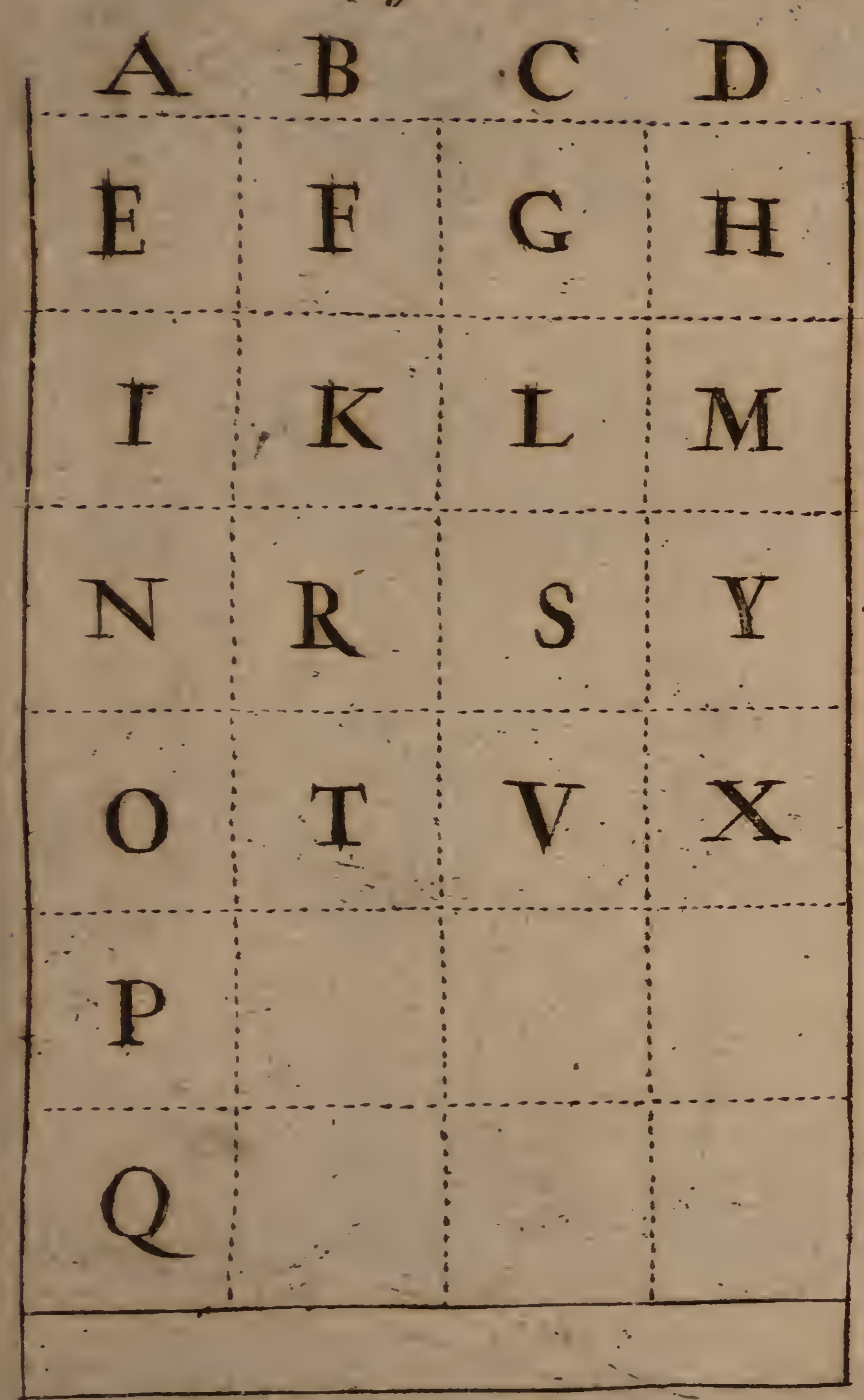


Fig. 2 *Pag. 25*

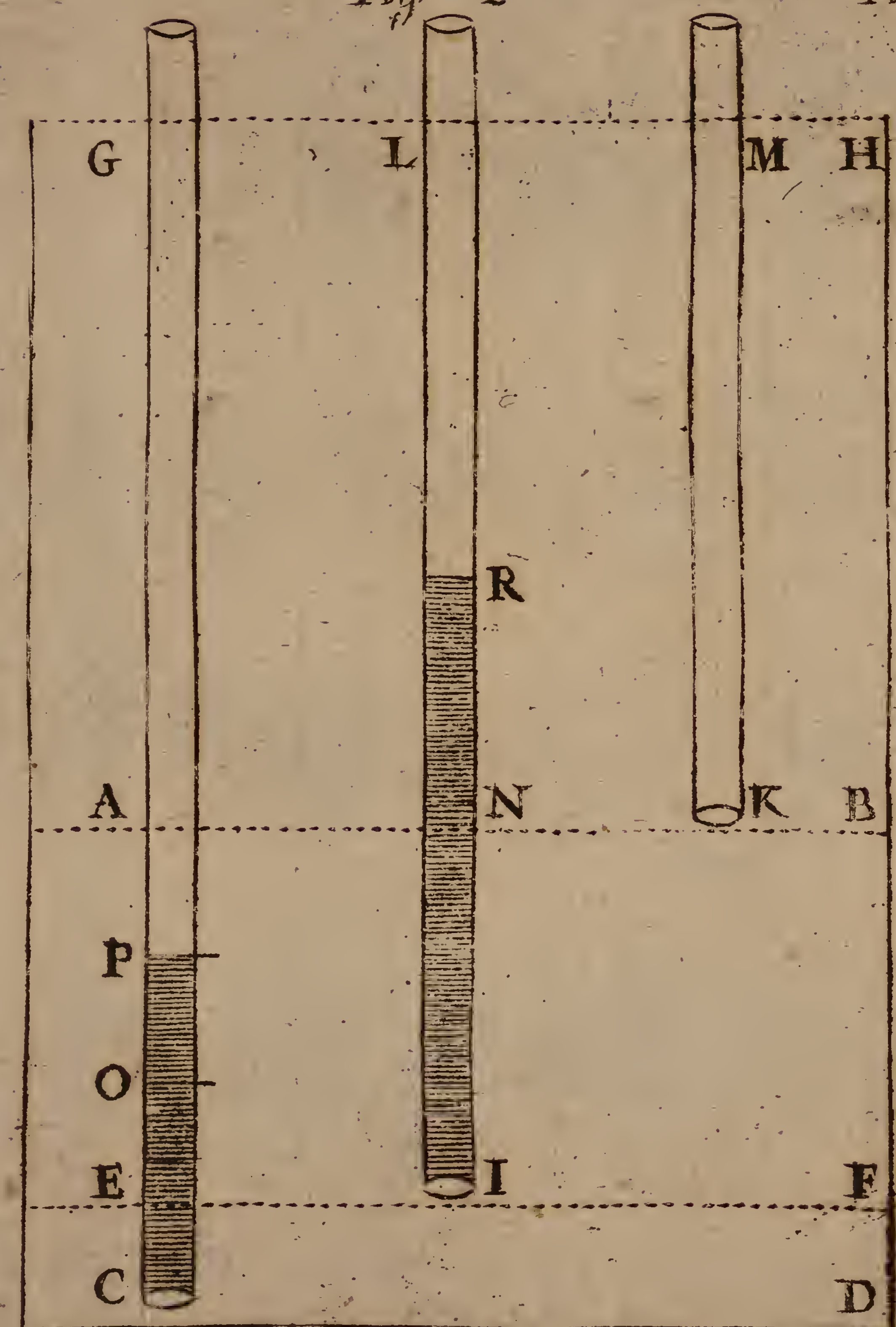


Plate 1.

Fig. 3 *Pag. 29*

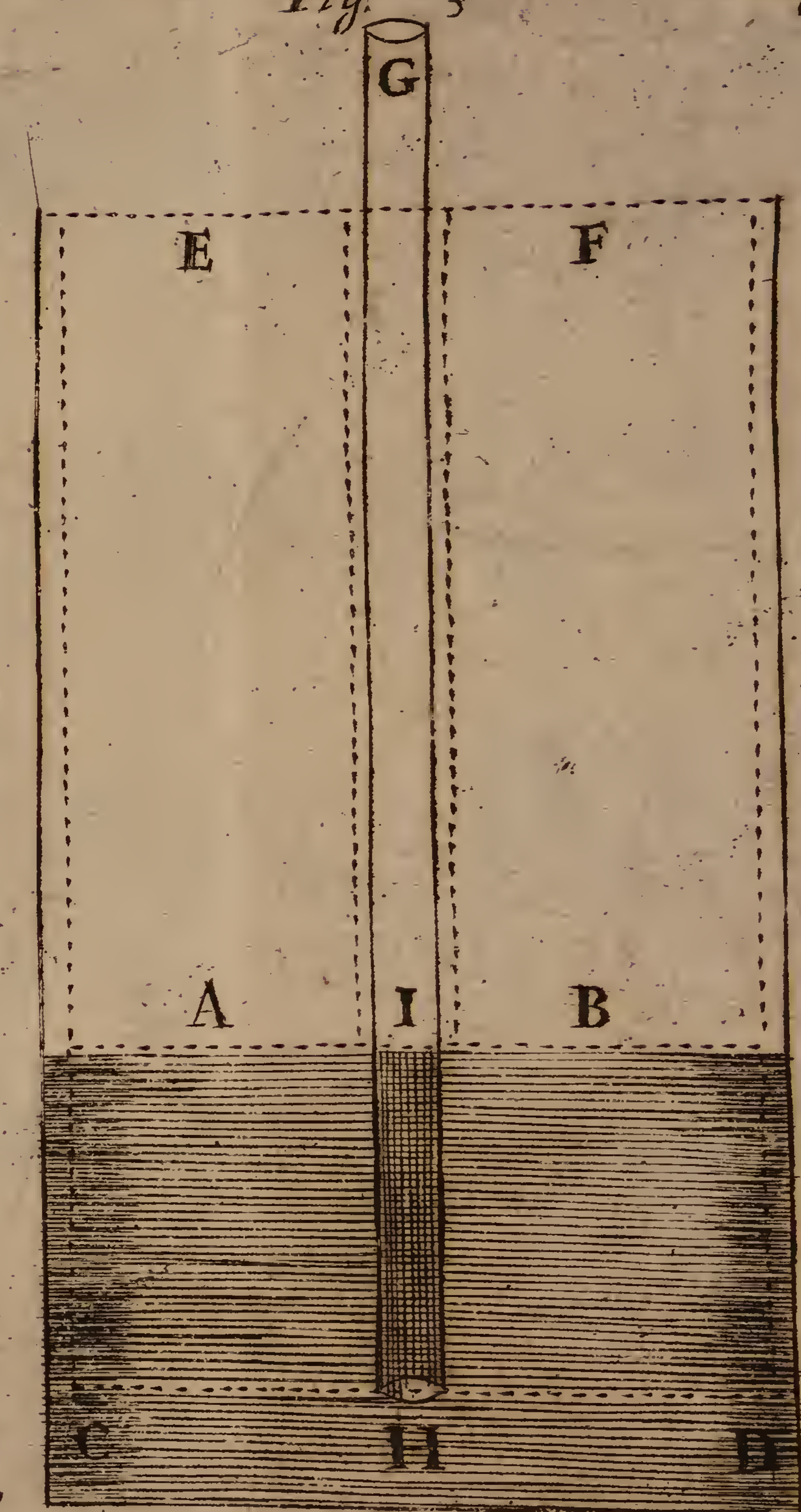
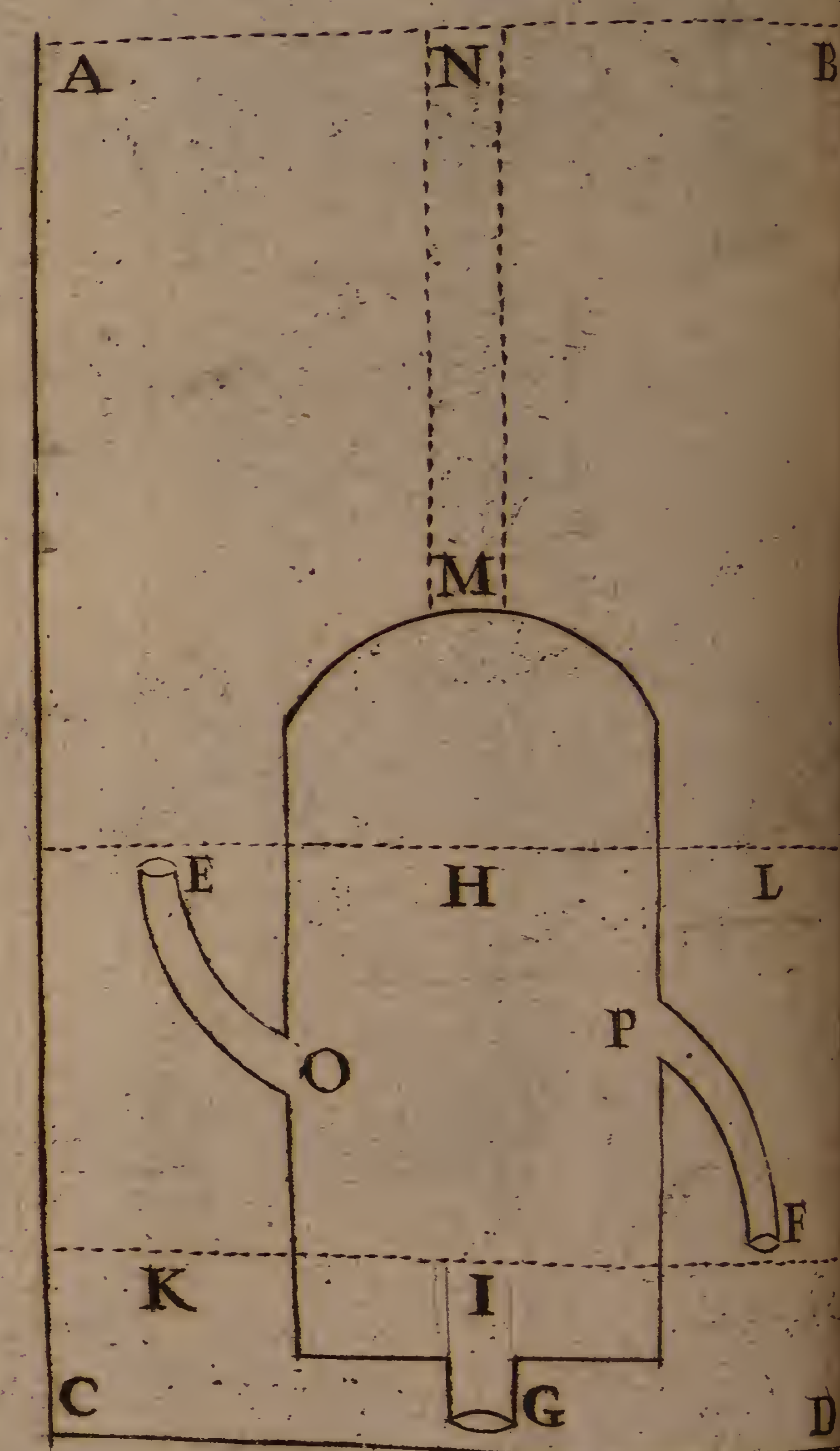


Fig. 4 *Pag. 31*



consequently a formal counter-ballance, or mutual sustentation. Be it so, yet because all these press uniformly, there can be no motion.

THEOREM XXX.

Fluids press not only according to perpendicular *Lines, but according to* crooked *Lines.*

Figure 4.

FOr proving this Proposition, let us suppose A B C D, to be a large Vessel full of VVater, as high as A N B, and a little Vessel lying within it, near to the bottom, closs above at M, but with an open orifice downward, as G, and having other two passages going in to it, upon the right, and left side, as E O, and F P. Now, I say, the Pressure of this VVater, is not only from N to M, in a *Straight* line downwards, but from E to O, and from F to P, by crooked lines. Nay, put the case this Vessel had no passage in to it, but by a *Labyrinth*, or entry full of intricate windings, yet the Pressure will be communicated, thorow all these, even to the middle of it: and which is more, the VVater H or I, within the Vessel, would be under the same degree of Pressure, with the VVater E or L, without, or with the VVater K or F. And which is strange, let us suppose both the entries E and F stopped, and nothing remaining open, but the hole G, which I judge no wider, then may admit the hair of ones head; yet thorow that smal hole, shall the Pressure be communicated, to the parts of the Water within, in as high a degree, as if the upper part of the Vessel E M L, were cut off, to let the Pressure come down directly. What is true in

in order to Water, the ſame is true in order to Air, or Mercury, or any other Fluid. For, though a houſe were built never ſo cloſs, without door, or window, yet if there remain but one ſmal hole in it, the Preſſure of the whole Atmoſphere, ſhall be tranſmitted thorow that entrie, and ſhall reduce the Air within the houſe, to as high a degree of *Benſil*, as the Air without.

THEOREM XXXI.

The Preſſure, and Benſil of a Fluid, that's in the Loweſt foot, *is equivalent to the weight of the* whole Pillar above.

Figure 5.

FOr underſtanding this Propoſition, let us ſuppoſe E F to be the loweſt foot of a Pillar of Air, cut off from the reſt, and incloſed in the Veſſel E F, ſix inches in Diameter, or wideneſs, and twelve inches high. Now I ſay, the *Benſil* and Preſſure, that's in that one foot of Air, is exactly of as great force and power, as is the weight of the whole Pillar of Air, from which it was cut off. Let A B be that Pillar of Air, which I ſuppoſe is ſix inches thick, and ſix thouſand fathom high. Take it, and weigh it in a Ballance, and ſay it weighs 500 pound, yet the Preſſure, and *Benſil*, that's in the Air E F, is of as much force: and if the one be of ſtrength by its weight, to move, *v. g.* a great *Clock*, the other by its *Benſil*, will be of as much. This propoſition is true alſo in order to Water. For put the caſe E F, were the loweſt of 34 foot of Water: in it will be found as much Preſſure, and force, as will be equivalent to the weight of the whole thirty three foot, from which

it

it was cut off. But here occurreth a difficulty; for if the Preſſure, and *Benſil* of the foot of Air E F, be equivalent to the weight of the whole Pillar of Air A B, which weighs 500 pound, then muſt the ſlender Pillar of Air C D, that's but two inches in diameter, be as heavy weighed in a ballance, as the thicker Pillar A B, which is abſurd. I prove the connexion of the two parts of the Argument thus: as the Benſil of the Air G H, is to the Benſil of the Air E F, ſo is the weight of the Pillar C D, to the weight of the Pillar A B: but ſo it is, that the Benſil of the Air G H, is equal in degree to the Benſil of the Air E F, according to the Theorem 21. Where it's ſaid, that the Preſſure of Fluids may be as much, in the leaſt part, as in the whole: therefore the Pillar C D, and the Pillar A B, muſt be of equal weight, when both are weighed together in the oppoſite ſcales of a Ballance, which is falſe, ſeing the one is far thicker, and ſo heavier then the other. There's no way to anſwer this objection, but by granting the Air G H, and E F, to be equal in *Benſil*, and yet the two Pillars unequal in weight, becauſe according to the 22 Theorem, the *Benſil* of a Fluid is one thing, and the *natural weight* is another.

THEOREM XXXII.

In all Fluids there is a Pondus *and a* Potentia, *a* weight *and a* power, *counterpoiſing one another, as in the* Staticks.

THat part of the *Mathematicks*, which is called *Staticks*, is nothing elſe, but the *Art of weighing heavy Bodies*; in which, two things are commonly diſtin-

E guiſhed

guished, *viz.* the *pondus* and the *potentia*, the *weight* and the *power*. 'Tis evident, while two things are counter-poising one another in the opposite scales of a Ballance, as *Lead* and *Gold*, the one being the *pondus*; the other the *potentia*. The same two are as truly found in the *Hydro-staticks*: for while the Mercurial Cylinder is suspended in the *Torricellian Experiment*, by the weight of the Air, the one is really the *pondus*, the other the *potentia*. Or while into a *Siphon*, with the two orifices upward, Water is poured, there arises a counterpoise; the Water of the one Leg counter-ballancing the Water of the other; this taking the name of a *pondus*, the other the name of a *potentia*. 'Tis evident also, while a surface of Water, sustains a Pillar of Water, this being the *pondus*, that the *potentia*: Or, while a surface of Water sustains a Pillar of Air, the Pillar of Air being the *pondus*, and the surface of Water the *potentia*. Or, while a surface of Quick-silver sustains a Pillar of Water or Air; the surface is the *power*, and either of the two is the *pondus*, or *weight*, as you please.

THEOREM XXXIII.

Fluid Bodies can never cease from motion, *so long as the* pondus *exceeds the* potentia, *or the* potentia *the* pondus.

THis is a sure Principle in the *Hydrostaticks*, which will appear most evident; while we pass thorow the subsequent Experiments, I shall only now make it appear by one instance, though afterwards by a hundred. In the *Torricellian Experiment*, lately mentioned, 'tis observed, that

that though the Pipe were never ſo long,that's filled with Mercury, yet the Liquor ſubſides, and falls down alwayes till it come twenty nine inches above the ſurface of the ſtagnant Mercury below. The reaſon whereof is truly this, ſo long as the Mercury is higher then the ſaid point, as long doth the *pondus* of it exceed the *potentia* of the Air; therefore the motion of it downward can never ceaſe, till at laſt by falling down,and becoming ſhorter, it becomes lighter, in which inſtant of time, the motion ends, both of them being now in *equipondio*, or in even-neſs of weight.

THEOREM XXXIV.

When two Fluids of different kinds are in æquilibrio *together, the height of the one Cylinder is in proportion to the height of the other, as the natural weight of the one is to the natural weight of the other.*

FOr underſtanding this Theorem,we muſt conſider,that when two Cylinders of the ſame kind, as one of Water with Water, or as one of Mercury with Mercury, are counterpoiſing one another, both are of the ſame altitude, becauſe both are of the ſame natural weight. But when the two are of different kinds, as a Cylinder of Air with Mercury,or as a Cylinder of Air with Water, or as a Cylinder of Water with Mercury, then it will be found, that by what proportion, the one Liquor is naturally heavier or lighter, then the other, by that ſame proportion, is the one Cylinder higher or lower then the other. For example, becauſe Air is reckoned 14000 times lighter then Quick-ſilver, therefore the Pillar of Air that counter-

poiseth the Pillar of Quick-silver in the *Torricellian Experiment*, is 14000 times higher. The one is 29 inches; and therefore the other is 406000 inches: which will amount to 33833 foot, or about 6766 fathom, counting five foot to a fathom. And because Air is counted 1000 times lighter then Water, therefore the Pillar of Air that sustains the Pillar of Water is 1000 times higher. The hight of Water by the Pressure of the Air is 34 foot; and therefore the hight of the Air is a thousand times 34 foot. And because Water is reckoned 14 times lighter than Mercury, therefore you will find, even by experience, that the Pillar of Water, that counterpoises the Pillar of Mercury, is 14 times higher. For if the Mercury be ten inches, the Water will be exactly 140. If it be 29 inches, the Water will be thirty four foot. The reason is evident, because if one inch of Mercury be as heavy naturally as 14 inches of Water, it follows of necessity, that for making of a counterpoise, to every inch of Mercury, there must be 14 of Water, and these in altitude, each one above another.

Hydroſtatical EXPERIMENTS,

For demonſtrating the wonderful *Weight*, *Force*, and *Preſſure* of the Water in its own Element.

EXPERIMENT I.

Figure *6*.

IN explicating the *Phenomena* of the *Hydroſtaticks*, and in collecting ſpeculative, or practical concluſions from them, I purpoſe to make choiſe of the plaineſt, and moſt eaſie Experiments, eſpecially in the entry, that this knowledge, that's not very common, and yet very uſeful, may be communicated to the meaneſt capacities. For, if at the firſt, any myſtical, or abſtruſe Experiments, ſhould be propoſed with intricate deſcriptions, they would ſoon diſcourage, and at laſt hinder the ingenuous Reader from making progreſs,

grefs. For, if a man do not take up diftinctly, the Experiment it felf firft, he fhall never be able to comprehend next the *Phenomena*, nor at laft fee the inferences of the conclufions. Next, though fome of the *trials* may feem obvious, yet they afford excellent *Phenomena*, by which many profound fecrets of Nature are difcovered. And if that be, 'tis no matter what kind they be of. Then, the grand defign here, is not to multiply bare, and naked Experiments; for that's a work to no purpofe, for it's like a foundation without a fuperftructure: but the intention is, not only to defcribe fuch and fuch *things*, but to build fuch and fuch Theorems upon them, and to infer fuch and fuch conclufions, as fhall make a ftately building, and give a man in a fhort time a full view of this excellent Doctrine.

For the firft Experiment then, prepare a Veffel of any quantity, as A B C D, near half full of Water, whofe furface is M H. Prepare alfo two Glafs-pipes, the one wider, the other narrower, open at both ends, which muft be thruft down below the Water, firft ftopping the two upper orifices E and F. This done, open the faid orifices, and you fhall fee the Water afcend in the wider to G, and in the narrower to H. Now, the queftion is, What's the reafon, why the Water did not afcend, the orifices E and F, being ftopped, and why it afcends, they being opened? To the firft part I anfwer, the Water cannot afcend, becaufe the imaginary furface of Water L K is equally and uniformly preft: for with what weight the outward Water M L, and H K prefs the faid furface, with the fame weight, doth the Air within the two Pipes prefs it. To the fecond part I anfwer, the Water afcends, becaufe the fame furface (the orifices E and F being opened) is unequally

preft:

preſt: for the outward Water M L, and H K, preſs it more, then the Air within the Pipes do. The difficulty only is, why it is equally preſt, the orifices E and F being ſtopped, and why it is unequally preſt, the ſaid orifices being once opened. To unlooſe the knot, I muſt ſhew the reaſon, why the Air within the Pipes, preſs the ſurface L K, with as great a burden, as the outward Water preſs it. For underſtanding this, you muſt know, that when the orifice I is thruſt down below the Water, there ariſeth a ſort of debate between the lower parts of the Water, and the Air within the Pipes, the Water ſtriving to be in at I, and the Air ſtriving to keep it out: but becauſe the Water is the ſtronger party, it enters the orifice I, and cauſeth the Air retire a little up, one fourth part, or ſixth part of an inch, above I, and no more, which is a real compreſſion it ſuffers. For the orifice E being ſtopped, hinders any more compreſſion, than what is ſaid; in which inſtant of time the debate ends, the Air no more yeelding, and the Water no more urging; by which means the Air having obtained a degree of *Benſil*, more then ordinary, by the Preſſure of that little quantity of Water, that comes in at I, preſſeth the part of the imaginary ſurface, it reſts upon, with as great weight, as the outward Water preſſeth the parts it reſts upon. But when the orifice E is opened, the outward water M L, and H K, preſs the imaginary ſurface L K more, than the Air within the Pipe can do. And the reaſon is, becauſe by opening the orifice above, the internal Air, that ſuffered a degree of *Benſil* more then ordinary, preſently is freed, and conſequently becomes of leſs force, and weight; which the Water finding, that hath a little entered the orifice I, inſtantly aſcends to G, it being leſs preſſed, then the Wa-

ter

ter without the Pipe. Now the reason, why it ascends no higher then G, is taken from the equal Pressure of the Body that rests upon the surface M G H: For, assoon as it comes that length, all the parts of the horizontal Plain of Water, is uniformly prest with the incumbing Air, both within the Pipe, and without the Pipe. The Water in going up, cannot halt mid-way between I and G, for then there should be an unequal Pressure in Fluids without motion, which is impossible; for the Water is still stronger then the Air, till once it climb up to G.

From this Experiment we see first, that in Water there is a Pressure and Force; because having opened the orifice E, which is only *causa per accidens* of this motion, the Water is prest up from I to G. We see secondly, that Fluid Bodies, can never cease from motion, till there be an equal Pressure among the parts, which is evident from the ascent of the Water from I to G, which cannot halt in any part between I and G, because of an unequal Pressure, till it once climb up to G. We see thirdly, that Fluid Bodies do not sustain, or counterpoise one another according to their *thickness* and *breadth*, but only according to their *altitude*; because there is not here any proportion between the slender Pillar of Water H K within the Pipe, and the outward Water that sustains it, I mean as to the *thickness*; therefore 'tis no matter, whither the Glass Tubs be wider or narrower, that are used in counterpoising Fluid bodies one with another. And this is the true reason, why 'tis no matter, whither the Tub of the *Baroscope* be a wide one, or a narrow one, seing the Air doth not counterpoise the Mercury, according to *thickness*, that's to say, neither the thickness of the ambient Air that sustains, nor the thickness of the Mercury that is

is ſuſtained, are to be conſidered; but only their *altitudes*. 'Tis true, the element of Air is fourteen thouſand times higher, then the Mercurial Cylinder, yet there is a certain and true proportion kept between their heights; ſo that if the element of Air, ſhould by *divine providence* become higher or lower, the height of the Mercury would alter accordingly.

EXPERIMENT. II.

Figure *6*.

TAke out of the Water, the wide Pipe E G I, and ſtopping the orifice I, pour in Water above at E, till the Tub be compleatly full. Having done this, thruſt down the ſtopped orifice I to the bottom of the Veſſel, and there open it, then ſhall you ſee the Water fall down from E to G, and there halt. The reaſon is taken from unequal Preſſure; for the Tub being full of Water from E to I, that part of the *imaginary* ſurface, upon which the Pillar of Water reſts, is more burdened than any other part of it, namely more then L or K; therefore ſeing one part is more burdened than another, the Cylinder of Water that cauſeth the burden, muſt ſo far fall down, till all the parts be alike preſt, in which inſtant of time, the motion ceaſeth. This leads us to a clear diſcovery of the reaſon, why in the *Baroſcope*, the Mercury falls from the top of the Tub of any height, alwayes to the twentieth and ninth inch, above the ſtagnant Quick-ſilver. For example, fill the Pipe N Q, which is ſixty inches high with Mercury, and opening the orifice Q, the Liquor ſhall fall out, and fall down from N, till it reſt at R, which

is twenty nine inch above the open orifice Q. The reason is the same, namely unequal Pressure, seing one part of the *imaginary* surface of Air X S, upon which the Cylinder of Mercury stands, is more burthened then the other next adjacent: therefore, so long and so far must the Mercury subside and fall down, till the part Q, upon which the Basis of the Pillar rests, be no more burthened, than the rest of the parts; in which instant of time, the motion ceaseth; and there happeneth an equal ballance, between the Silver within the Tub, and the Air without. If it be said, I see a clear reason, why the outward Water M L, ought to sustain the inward G I, but cannot see, why the outward Air T Z S and V R X, ought to sustain the inward Mercury R X: neither do I see a reason, why it should halt at R, as the Water rests at G. I answer, though sense cannot perceive the one, as evidently as the other, yet the one is as sure as the other. For taking up the reason why it halts at R, 29 inches above X, you must remember, from the 25 Theorem, that the Pressure of the Air upon Bodies, is equivalent to the weight of 34 foot of VVater perpendicularly, or 29 inches of *Quick-silver*. The Pillars of Air then T Z S, and V R X, being as heavy each one of them, as two Pillars of Mercury, each one of them 29 inches high, it follows of necessity, that the Mercury within the Tub, must be as high as R. 'Tis no wonder to see the *Silver* halt at R, provided R X, and Z S, were two bulks of Mercury, environing the Pipe, as the outward VVater environs the wider and narrower Pipe. Neither ought any to wonder, when the *Silver* falls down, and rests at R, nothing environing the Pipe but Air, seing the Pressure of the Air is equivalent to the weight of 29 inches of *Quick-silver*.

This

This Experiment is easily made: take therefore a slender Glass-pipe of any length, beyond 30 inches, open at both ends; but the lower end Q, must be drawn so small by a flame of a Lamp, that the entry may be no wider, than may admit the point of a small needle, or the hair of ones head. Then stopping the said orifice, pour in Mercury above at the orifice N, till the Pipe be compleatly full. Next, close the said orifice with wet Paper, and the pulp of your finger; and opening the lower orifice, you shall find, (which is very delightful to behold) the Mercury spring out, like unto a small silver threed, and falling down from the top N, shall rest at R, the motion ceasing at the narrow orifice Q. This shews evidently, that there is not need alwayes of stagnant Mercury, for trying the *Torricellian Experiment*; but only when the mouth of the Pipe below is wide: for being narrow, the *silver* runs slowly out, and consequently subsides slowly above, and coming down slowly to R, there rests. But when the mouth is wide below, the *silver* falls down so quickly, that it goes beyond R, before it can recover it self, which recovery would never be, unless there were stagnant Mercury to run up again.

From what is said, we see first, that when one part of a surface of Water or Air, is more burthened than another, the burthened part presently yeelds, till it be no more burthened than the other. This is clear from the falling down of the Water from E to G, which cannot be supported by the part I, because more burthened than the rest. We see secondly, that the element of Air, rests upon the surfaces of all bodies with a considerable weight; otherwise it could not sustain the Water, before it fall down from E to G: for if it did not rest upon the surface

M H, with weight, the Water could never be suspended; seing the application of the finger to the orifice E, is only the *accidental cause* of this sustentation. We see thirdly, that according to the difference of *natural weight*, between two Fluids, so is the proportion of *altitudes* between two of their Cylinders: therefore Air being reckoned 14000 times lighter then Mercury, it followes that the Cylinder of Mercury sustained by the Air, must be 14000 times lower and shorter, than the Cylinder of Air that sustaines it; which appears from this experiment to be true, seeing by the Pressure of the Air, which is thought to be about 7000 fathom high, 29 inches of Mercury is supported between R and X. In a word, if Air be naturally 14000 times lighter than Mercury, which is very probable; then must the altitude of it, commonly called the *Atmosphere*, be fourteen thousand times, nine and twenty inches, that is 406000, or of feet 33833.

EXPERIMENT III.

Figure 6.

WHile the outward, and inward Water are of the same altitude, withdraw the inward Air E G by suction, or by any other device you think fit, and you will find the Water rise as high as E, which I suppose to be 34 foot above M G H. The same *Phenomenon* happens, in taking the Air out of the narrow Pipe F K. The reason is still unequal Pressure; for in removing the Air, that's within the Pipe, the part of the surface M, and the part H, remaines burthened, while the part G is freed of its burden; therefore this part of the surface, being liberated

rated of its burden, that came down through the Pipe, instantly rises, and climbs up as far, as the outward Air resting upon M and H, can raise it, which is to E 34 foot: for the Pressure of the Air upon the surfaces of all Waters, according to the 25 *Theorem*, being equivalent to the weight of 34 foot of Water, must raise the said Water in the Pipe 34 foot. You do not wonder, why it rises from I to G, as in the first experiment; no more ought you to wonder, why it rises from G to E, seing the weight of the Air, doth the same thing, that 34 foot of Water resting upon the surface M H, would do.

From this experiment we see first, that the Pressure of the Air, is the proper cause of the motion of Water, up thorow *Pumps* and *Siphons*, or any other instrument, that's used in Water-works of that kind; for if the weight of the Air, resting upon the surface M H be the cause, why the Water climbs up from G to E, the same must be the cause, why the stagnant Water followes the *Sucker* of the *Pump*, while it's pulled up. And the same is the cause, why Water ascends the Leg of a *Siphon*, and is the cause, why motion continues after suction is ended. We see secondly, that every Pressing Fluid hath a *Sphere of activity*, to which it is able to raise the Fluid, that is pressed. This is evident in this experiment, because the Pressure of the Air resting upon M H, is able to raise the Water, the hight of E in the wide Pipe, and the hight of F in the narrow, and no further, even though the said Pipes were far longer: and this altitude and highest point is precisely 34 foot between Air and Water. We see thirdly, that 'tis all one matter, whether *Pumps* and *Siphons* be wider or narrower, whether the tub of the *Baroscope* be, wherein the Mercury is suspended, of a large Diameter, or of a lesser Diameter.

Diameter. This is alſo evident from the ſame experiment; ſeing there is no more difficulty in cauſing the Water aſcend the wide Pipe, than in cauſing it aſcend the narrow one. And the reaſon is, becauſe the preſſing Fluid reſpects not the preſſed Fluid, according to its *thickneſs* and *breadth*; but only according to its *altitude*. Therefore its as eaſie for the Air, to preſs up Water through a *Pump* four foot in Diameter, as to preſs it up through a *Pump*, but one foot in Diameter.

EXPERIMENT IV.

Figure 7.

THis Schematiſm repreſents a large Veſſel full of Water, whoſe firſt and viſible ſurface is D E H K. The ſecond, that's imaginary is, L I, ſix foot below it. The third of the ſame kind, is M G, ſix foot lower. The fourth, is N F O, ſix foot yet lower. The laſt, and loweſt, is A B C. There are here alſo four Tubs, or rather one Tub under four divers poſitions, with both ends open. After this Tub D A is thruſt below the Water, till it aſcend, as high as D in it, lift it up between your fingers, till it have the poſition of the ſecond Pipe E F, and then you ſhall ſee, as the orifice of the Pipe aſcends, the Cylinder of Water fall out by little and little, until it be no longer than E F. Again, lift it further up, till it have the poſition of the Pipe H G, then ſhall you find the Cylinder of Water become yet ſhorter. Laſtly, if it be ſcituated, as the Pipe K I, the internal Water becomes no longer than K I. The reaſons of theſe *Phenomena* are the ſame; namely unequal Preſſure; for the Orifice A being lifted up as high

high as F, it comes to the imaginary surface N O, which is not under so much Pressure, as the other is; therefore one part of it being more burdened, than another, namely the part upon which the Cylinder of Water rests, it presently yeelds, and suffers the Cylinder to become shorter, and lighter, till it become no heavier, then is proportionable to its own strength. To make this reason more evident, it is to be noted, that no surface of Water is able to support a Cylinder higher then its own deepness, that is to say, if a surface be 40 foot deep, it is able to sustain a Cylinder 40 foot high, and no more: therefore the surface N O, being but 18 foot deep, it cannot sustain a Cylinder 24 foot long: for if that were, then the *Potentia*, should be inferiour to the *Pondus*; which is impossible in the *Hydrostaticks*. In effect, it were no less absurdity, then to say, 18 ounces are able to counterballance 24. For a second trial, lift up the same Pipe higher, till it acquire the position of the Tub G H; in this case, the Cylinder of Water within it, becomes yet shorter, even no longer, than G H. The reason is the same, namely unequal Pressure; for when a Cylinder of Water 18 foot high, comes to rest upon this surface, that is but 12 foot deep, it makes one part of it more burdened then another; therefore the part that is more prest, presently yeelds, and suffers the Cylinder to fall down, till the *Pondus* of it, become equal to its own *Potentia*. For the last trial, lift up the Tub, till it acquire the position of the Pipe K I: in this case, the Water within it becomes no longer then K I, the surface L I, that is but six foot deep, not being able to sustain a Cylinder 12 foot high.

From this Experiment we see first, that in all Fluid Bodies there is a Pressure, which is more or less, according to the

the deepness of that Fluid; this is evident from the four several surfaces; there being more Pressure and force in the lowest A B C, then in the next N O; and more in this, then in the surface M G; and more in this, then in L I. We see secondly, that in all Fluids, there is a *Pondus* and a *Potentia*; which two are alwayes of equal force, and strength; the *Potentia* is clear and evident in the surface, by supporting the Pillar; which Pillar is nothing else, but the *Pondus* supported. And that they are alwayes of equal strength, is most evident also; for when you endeavour to make the *Pondus* unequal to the *Potentia*, in making a surface 18 foot deep, to support a Pillar 24 foot high, they of their own accord become equal; the Pillar becoming shorter, and suitable to the strength of the surface that sustains it. We see thirdly, that 'tis impossible for one part of the same Horizontal surface, to be more burdened then another: for when you endeavour to do it, by setting a longer Pillar upon it, the part burdened instantly yeelds, till it be no more prest, then the next part to it. We see fourthly, that the inequality, that is between the *Pondus* and the *Potentia* in Fluids, is the proper cause of the motion of Fluids. For when you endeavour to make a surface 30 foot deep, sustain a Pillar 40 foot high, this inequality is the true cause, why the Pillar subsides, and falls down, and why the surface yeelds, and gives way to it. And this inequality is the true cause, why the motion of Water thorow *Siphons* continues. For understanding this, you must conceive a *Siphon*, to be nothing else, but a crooked Pipe with two legs; the one drowned among Water, the other hanging in the open Air. The use of it is, for conveying Wine or Water from one Vessel to another, which is easily done by suction. Now after suction is ended,

ed, the motion of the Water continues, till the ſurface become lower, then the orifice out of which it runs. The true reaſon then, why the Water flows out, is the inequality between the *Potentia* of the Air, and the *Pondus* of the VVater; the *Pondus* being ſtronger then the *Potentia*. For in Air as in VVater, we muſt conceive Horizontal ſurfaces; and theſe ſurfaces to be endowed with Preſſure and force, as are the ſurfaces of VVater. Now when the leg of a *Siphon* is hanging in the Air, it muſt reſt upon one ſurface or another, and conſequently the VVater in it, muſt reſt upon the ſame ſurface. If the *Potentia* of the ſurface be ſtronger, then the *Pondus* of the VVater; the VVater is driven backward, which alwayes comes to paſs, when the orifice is higher, then the ſurface of the VVater of the Veſſel, among which the other leg is drowned. If the *Potentia* of the ſurface of that Air, be of equal power and ſtrength, with the *Pondus* of the VVater, the VVater goeth neither backward, nor forward, but ſtands in *equilibrio*: this happens, when the orifice is neither higher, nor lower, than the ſurface of the VVater in the Veſſel. But if the *Potentia* of the ſurface of the Air be weaker, than the *Pondus* of the VVater; in this caſe, the Air yeelds, and ſuffers the VVater to run out, even as a ſurface 30 foot deep, yeelds to a Pillar of VVater 40 foot high. The ſame inequality is the reaſon, why VVater climbs up the Pump; why VVater climbs up a Pipe, when a man ſucks with his mouth. Before ſuction, the *Potentia* that's in the ſurface of VVater, among which the end of the Pipe is drowned, is of equal force with the *Pondus* of the Pillar of Air, that comes down thorow the Pipe, or Pump; but aſſoon as a man begins to ſuck, the ſaid Pillar of Air becomes lighter; and the VVater finding this, preſently aſcends. The ſame

G is

is the reaſon, why the Mercury falls down to 29 inches in the *Baroſcope*, and no further: for as long as the *Pondus* of the Pillar of Mercury, exceeds the *Potentia* of the ſurface of Air, ſo long doth the motion continue; and when both are become equal in force, the motion ceaſeth. VVhen the Glaſs-tub is 40 inches long, and filled with Mercury, and inverted after the common manner, you are endeavouring as it were, to cauſe a ſurface 29 inches deep, ſuſtain a Pillar 40 inches high, which is utterly impoſſible in Fluids. It is judged by many a wonder to ſee the deflux of the Mercury in the *Baroſcope*; but in effect, there's no more cauſe of admiration in it, than to ſee the Cylinder of Water grow ſhorter, by lifting the Pipe up from one ſurface to another.

From this Experiment, we ſee the true reaſon, why the Mercurial Cylinder of the *Baroſcope* becomes ſhorter and ſhorter, according as a man climbs up a mountain with it. For at the root of the hill, the ſurface of Air, that ſuſtains the Pillar of Mercury, is of greater force, than the ſurface at the middle part: and this is ſtronger than any ſurface at the top. The Pipe therefore being carried up from one ſurface to another, the Mercury in it, muſt ſubſide, and fall down, even as the Water falls down, and becomes ſhorter, by lifting the Pipe from the ſurface A B C D to the ſurface N O. And as the whole VVater would fall down, if the orifice I, were lifted above the ſurface D E H K, ſo if the *Baroſcope* could be carried ſo high, till it came above the top of the Air, the whole Mercurial Cylinder would ſurely fall down. And as by thruſting down the ſaid Pipe to the bottom of the Veſſel again, as the Pipe D A, the VVater aſcends in it; ſo by bringing down the *Baroſcope* to the earth again, the whole 29 inches would riſe again.

EXPE-

EXPERIMENT V.
Figure 8.

Fill the Vessel A D G H with VVater to the brim. Next, thrust down the open orifice of the Tub D A, to the bottom, and you shall see the VVater ascend in it, as high as D, according to the first experiment. When this is done, recline the said Pipe, till it ly as B E, and you shall find the Pipe, compleatly full of VVater. Next, erect the same Tub again as D A, and you shall see the Cylinder of VVater fall down, and become shorter, as at first. For salving this *Phenomenon*, and such like, I must suppose this VVater to be 50 inches deep, and the Tub I A, and B E 90 inches long: and the said Tub in reclining, to describe the quadrant of a Circle F E G. Now the question is, why there being but 50 inches of Water in the Tub, while erected, there should be 60 in it, when it is reclined? Secondly, why there should be 90 inches of Water in the Tub B E, and but 50 in it, when it stands Perpendicular, as D A? If you reply, because there are 90 inches *in recta linea* between the point B, and the point E, and but 50 between A and D. But this will not answer the case; because, if you stop the orifice E, with the pulp of your Finger, before it be erected, you will find the Tub remain full of VVater, even while it stands Perpendicular; and fall down, when the orifice is opened. Or, while the Tub stands Perpendicular, stop the orifice I, and recline it as B E: yet no more Water will be found in it, than 50 inches: but by unstopping the said orifice, the VVater climbs up from R to E, and becomes 90 inches. Now, what's the reason,

why it runs up from R to E, and why it falls down from I to D? I answer then, the VVater must run up from R to E, because of the inequality, that's between the *Pondus* of the Cylinder B R, and the *Potentia* of the surface of VVater A B C, that supports the said Cylinder. For understanding this, know, while the Tub is erected, there is a perfect equality, between the weight of the Pillar A D, and the force or *Power* of the surface that sustains it, seing a surface 50 inches deep, supports a Pillar 50 inches high. But assoon as the Tub is reclined, there arises ane inequality between the saids two parties, the *Pondus* of the Cylinder becoming now less than before. If you say the quantity of the VVater is the same, namely 50 inches, in the reclined Tub, as well as in the Perpendicular. I grant the quantity is the same, but the weight is become less. Now the reason, why the same individual VVater, is not so heavy as before, is this; there are 40 ounces of it, supported by the sides of the Tub within; which were not, while the Tub was erected: for in this position, the whole weight of the Cylinder rests upon the surface: but while the Tub is reclined, the said surface is eased, and freed of 40 ounces of it; this 40, resting and leaning upon the sides of the Pipe within. The surface then, finding the said Cylinder lighter now than before, instantly drives it up from R to E, 40 inches. And likewise, when the reclined Pipe is made Perpendicular, the Water falls down from I to D, because of the inequality, that's between the *Pondus* of the Pillar, and the *Potentia* of the surface; this surface 50 inches deep, not being able to support a Pillar 90 inches high, for if this were, then one part, should be more burthened than another, which is impossible.

It is to be observed, that by how much the more, the

Tub

Tub is reclined from a Perpendicular, towards the horizontal surface A B C, by so much the more growes the inequality, between the *Pondus* and the *Potentia*, and that according to a certaine proportion. Hence is it, that the Tub being reclined from 60 degrees to 50, there arises a greater inequality between the *Pondus* of the Cylinder, and the *Potentia* of the surface, than while it is reclined from 70 to 60: and more yet in moving from 50 to 40, than in moving from 60 to 50, and so downward, till it be horizontal, in which position, the whole *Pondus* is lost. And contrariwise, while the Pipe is elevated, the *Pondus* begins to grow; and growes more, being lifted up from 10 to 20, than from 1 to 10: and yet more in travelling from 20 to 30, than from 10 to 20, and so upwards, till it be Perpendicular, in which position, the Cylinder regaines the whole *Pondus* and weight, it had. This proportion is easily known, for its nothing else, but the proportion of *Versed Sines* upon the line F B; for according to what measure, these unequal divisions become wider, and wider from 90 to 1, according to the same proportion does the *Pondus* of the Cylinder become less and less: and contrariwise, according to what proportion the said divisions become more and more narrow from 1 to 90, according to the same measure and rate, does the *Pondus* of the Cylinder become greater and greater.

From this experiment we see first, that two Cylinders of Fluid bodies, differing much in quantity, may be of the same weight: because though the Cylinder B E 90 inches long, be far more in quantity, than the Cylinder D A, that's but 50, yet both of them are of the same weight, in respect of the surface that sustaines them. If it be said, the one is really heavier, than the other, notwithstanding of all

all this. I anſwer, it is ſo indeed, in reſpect of the *Libra*, or Artificial Ballance, that we commonly uſe in weighing of things: but it is not ſo in reſpect of this *Natural Ballance*, if I may ſo ſpeak, wherein Fluid bodies are onely weighed after this manner. We ſee ſecondly a clear ground for ſetting down the ninth Theorem, namely, that in all Fluid bodies a twofold weight may be diſtinguiſhed, one *Senſible*, another *Inſenſible*: becauſe the *Senſible* weight of the Cylinder of Water B E, remaines ſtill the ſame, even though it ſhould be reclined to G; for take it out, and weigh it in a Ballance, it will be as heavy the one way as the other. But it is not ſo with the *Inſenſible* weight; ſeeing the Tub begins no ſooner to recline, but aſſoon it begins to diminiſh, and grows leſs. This *Inſenſible* weight is nothing elſe, but the *ſenſible* weight conſidered after another manner. For look upon the weight of the Pillar of Water B E, as it weighs in a pair of Scales, it is then *Senſible*, and weighs ſo many ounces, and cannot be more or leſs: but look upon it in reference to the *Potentia* of the ſurface, that ſuſtains it, it is then *Inſenſible* as to us: for though a man ſhould put his hand below the Water, and endeavour to find the weight of the ſaid Pillar, yet he ſhall not find it, though that part of the ſurface upon which it reſts, doth really (if I may ſo ſpeak) find the weight of it. And as it is *Inſenſible*, ſo is it ſometimes more, and ſometimes leſs, according as the Tub is elevated, or reclined: now theſe two being put together, gives a very probable ground for this diſtinction. We ſee thirdly, that the *Pondus* or weight of Fluids, doth not only preſs according to Perpendicular lines, but according to lines falling obliquely upon the imaginary ſurface; ſo doth the weight of the Pillar of Water B E, preſs the ſurface A B C. We ſee fourthly, that

Fluid

Fig. 5 *Pag. 32*

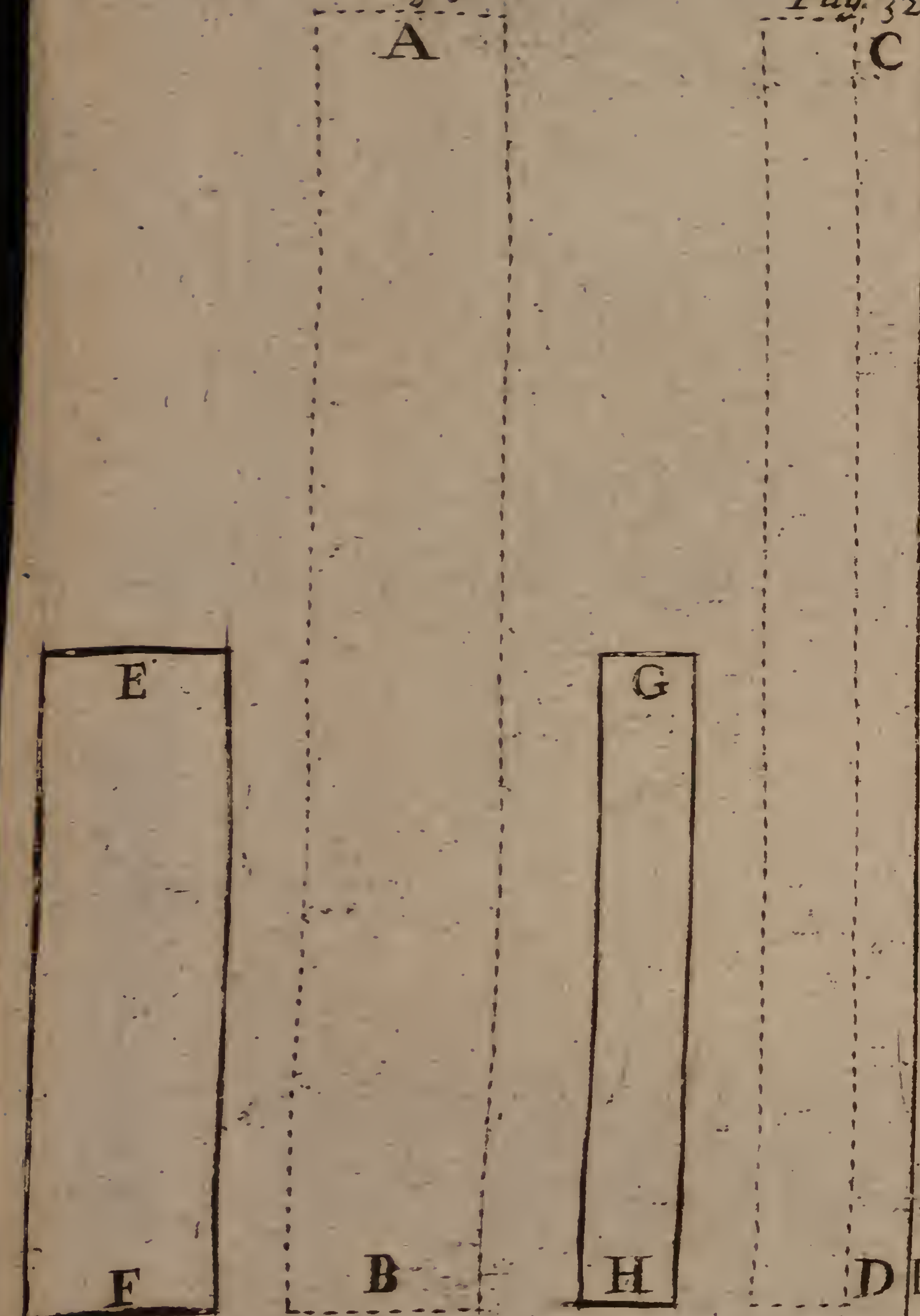


Fig. 6 *Pag. 37*

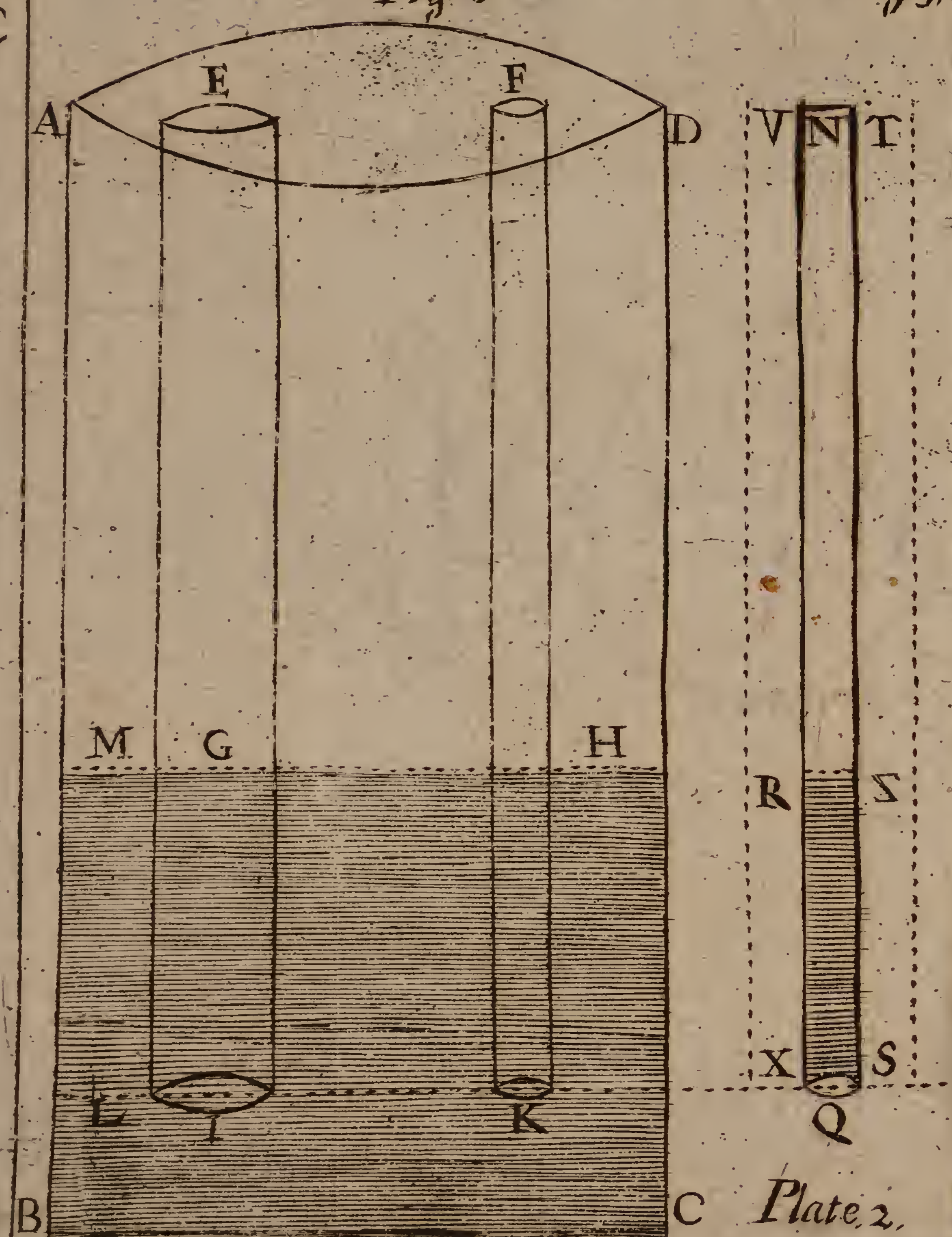


Plate 2.

Fig. 7 *Pag. 46*

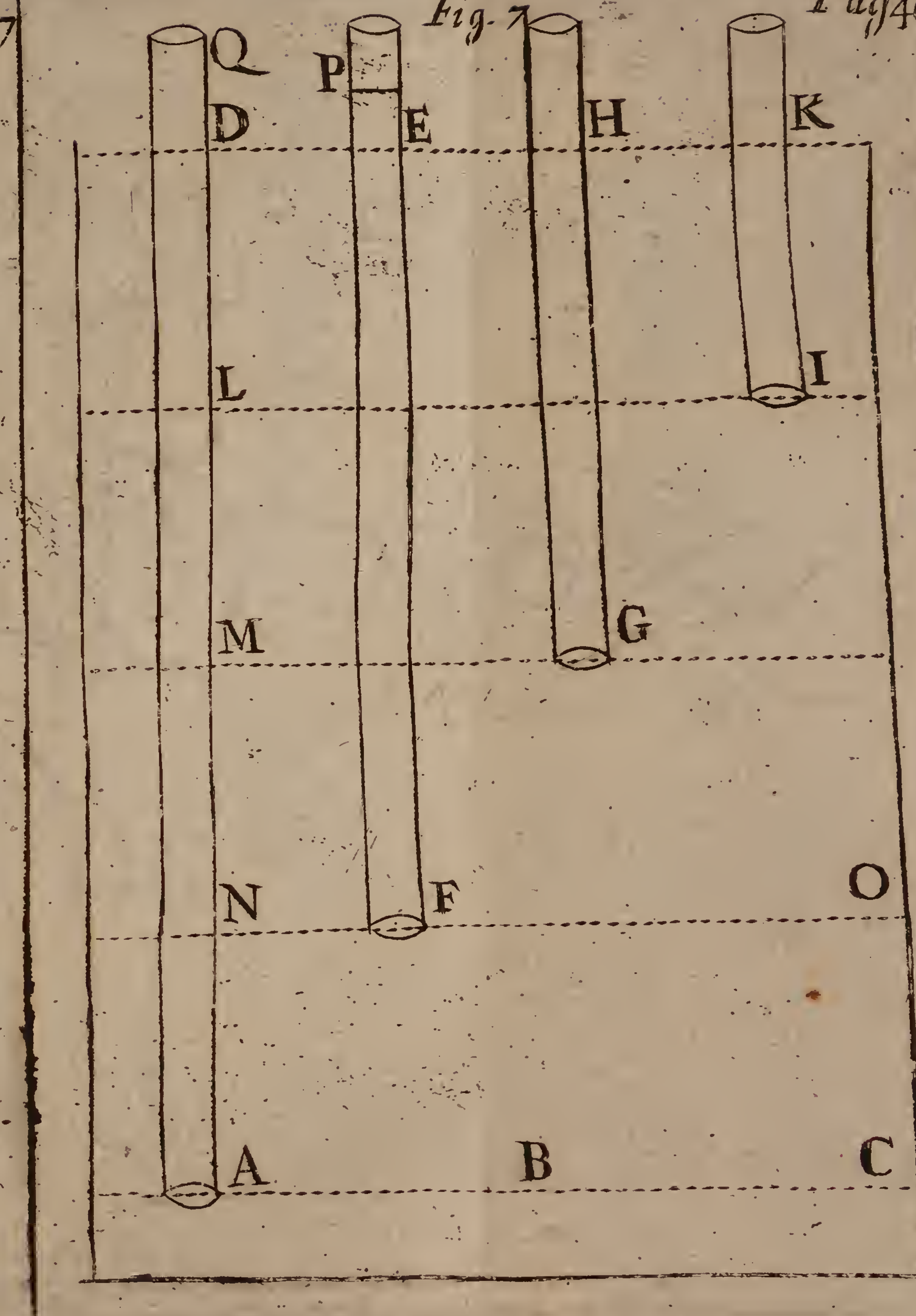
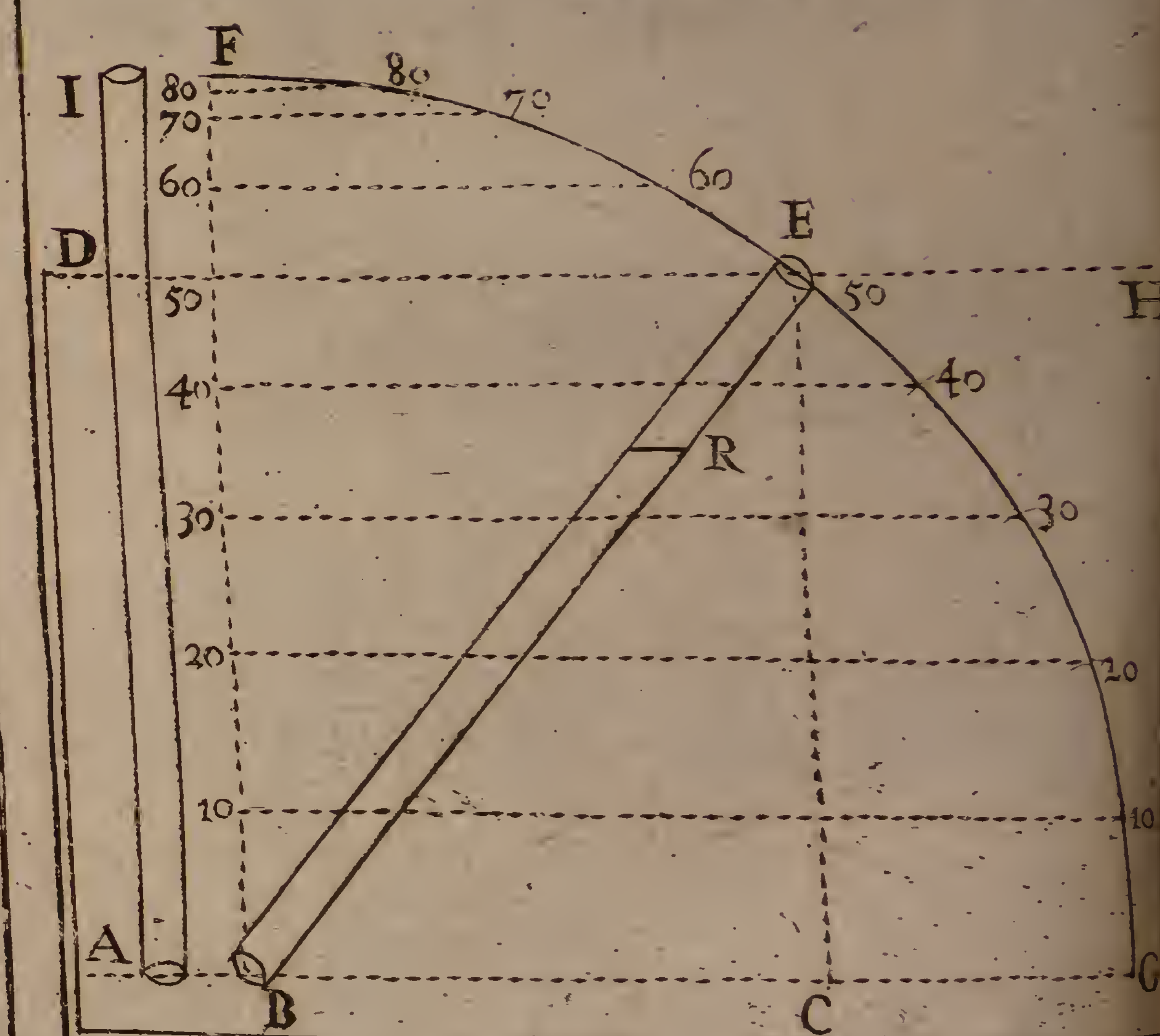


Fig. 8 *Pag. 55*



Fluid Bodies, do counterpoise one another, according to *Altitude* only: for put the case, the Pipe B E, were ten times wider then it is, yet will the surface sustain the Water in it, provided the Pipe keep still the same position of *Altitude*, namely 50 degrees: the reason seems to be this; for if the *Base* of the Pillar become more in Diameter, it necessarily requires a larger part of the surface to rest upon; which larger part is really stronger than the lesser part, as will be shewed afterwards. From this Experiment we see lastly, an evident reason, why the Mercurial Cylinder in the *Baroscope* runs up, and fills the empty space, when the Pipe is reclined, and why it runs down, when the Tub is erected again. In effect, the reason is the same, namely, an inequality between the *Pondus* of the Quick-silver, and the *Potentia* of the surface of the Air: for when the Tub begins to recline, the *Pondus* begins to rest upon the side of the Tub within; by which means the *Potentia* of the surface finding the burden less, instantly thrusts up the stagnant Mercury to supply that loss, seing two Fluids cannot counterpoise one another, unless they be in *æquilibrio*. And contrariwise, assoon as the Tub begins to be erected, the *Pondus* of the Mercury begins to grow, and so overcomes the *Potentia* of the surface, till by falling down it can do no more.

EXPERIMENT VI.

Figure 9.

THis Schematism represents a Vessel full of Water, whose first and visible surface is H I K; the second, which is imaginary, is E F G; the third, A B C D.

Besides

Besides these three in Water, conceive a fourth in the Air, above the Water, namely L M N. Upon this aërial surface, rests the orifice M, of the Tub T M, open above. Upon the surface E F G, is standing the mouth F, of the Pipe S F. And upon the surface A B C D, stands the Pipe R B, open at both ends. After the orifice B is drowned below the VVater, you will find the Liquor rise from B to H. Then close with the pulp of your Finger the mouth R; and lift the Pipe so far up, till it have the Position of the Pipe S F; and you shall see the VVater hing in it between F and O. Lastly, bring the said orifice compleatly above the VVater, till it have the position of the Tub T M; yet shall the VVater still hing in it, as M P. The first question is, what sustains the VVater I O; for the part F I, is sustained by the ambient VVater? I answer, it cannot be the pulp of the Finger closing the orifice S; for though, by taking away the Finger, the VVater O I falls down, and by putting to the Finger, it is keeped up, yet this proves not the pulp of the Finger to be the principal, and immediat cause. I say then, the VVater O I is suspended by the weight of the incumbing Air, resting upon the surface H I K. For understanding this, consider, as I said before, 25. Theorem, that the Pressure of the Air upon all Bodies, is just equivalent to the weight of 34. foot of VVater. Hence then is it, that if the Air be able to sustain a Pillar of VVater, 34 foot high, it must be able to sustain the short Pillar O I, that exceeds not four foot. The second question is, whether the part F, be equally burthened with the part E, or G; for it would seem not, seing the VVater O I F, is but four foot high; whilest upon E or G is resting, not only more then a foot of VVater to the top H I K, but the

the whole weight of the *Atmoſphere* upon the ſaid top is reſting, which is equivalent to the burden of 34 foot of VVater. I anſwer, there's more to be conſidered, than that four foot of VVater, which in it ſelf is but of ſmall burden, therefore to this we muſt add the weight of the Air between O and S, within the Pipe (remember that the orifice S is ſtopped with the pulp of the Finger) which in effect will be as heavy as 31 foot of VVater. Put the caſe then, F, to be one foot below the firſt ſurface H I K, and the VVater O I to be three foot, then ought the Air O S, to have the weight of 31 foot, becauſe the ſurface E F G is able to ſupport a Pillar of 35 foot. This I prove, becauſe the part E, *de facto*, ſuſtains 35 foot, becauſe the Air above is equivalent to 34 foot of it, and there is a foot of VVater between it and the top, namely between E and H. The third queſtion is, how it comes to paſs, that the Water ſtill remains in the Pipe, after the orifice M is brought above the ſurface of the Water; for there is here no ſtagnant Water guarding it, as guards the orifice F. I anſwer, that the *baſe* M, of this Pillar of Water P M, as really reſts upon the horizontal ſurface of this Air L M N, as a Cylinder of Braſs or Timber reſts upon a plain Marble Table, and after the ſame manner. Remember that the orifice T is ſtopped all this time, with the pulp of the Finger. If it be ſaid, that the part M, is more burdened then the part N, ſeing it ſuſtains four foot of Water, which the part N ſupports not; and the Air P T within the Pipe alſo, which is of as much *Benſil* and Preſſure, as the Air N Y is of. For clearing of this difficulty, conſider, that the Pillar P M is ſhorter now than befo e; for the orifice M coming up from D, ſome inches of Water falls out, as will be found by experience. Sup-

pose then, that of four foot, six inches fall out; if this be, then the inclosed Air between P and T, must be six inches longer, if this be, then of necessity the Bensil of it must be proportionably remitted and slackened: whence follows by *Metaphysical* necessity, that it cannot burden the Water P M, with as much weight as it had, and consequently the surface of Air cannot be so much burdened. It must then be no more burdened with them both together, than it is with the single Pillar of Air Y N. If then the Water P M, be three foot and an half, the weight of the enclosed Air T P, must be exactly the weight of thirty foot of Water and an half.

From this experiment, we see first the Pressure of the Air, for by it the Water O I is suspended, and by the same pressure is the Water P M suspended. We see secondly, that in Air, there is a power of dilating it self, and that this dilatation never happens, without a relaxation of the *Bensil*. We see thirdly, that one Fluid cannot sustain another, unless the *Potentia* of the one, be equal to the *Pondus* of the other, as is clear from the Aerial surface, that cannot sustain the whole four foot of Water, but suffers six inches of it to fall out, that the *Pondus* of the rest, and the Air above it, may become equal to its own *Potentia*. We see fourthly, that Fluid Bodies have not only a power of pressing downward, but of pressing upward likewise: as is clear from the Water O I, that's suspended by the Air pressing down the surface of Water H I K. It presseth upward also, while it supports the Water P M. This Experiment also answers a case, namely, whether or not, it is alwayes needful to guard the orifice of the Tub of the *Baroscope* with stagnant Quick-silver? I say then, it is not alwayes needful, provided the orifice be of a narrow

diameter;

diameter; for experience tells, that while it is ſuch, the Mercury will ſubſide, and halt at 29 inches above the orifice, though no ſtagnant Mercury be to guard. In making this trial, the orifice muſt be no wider, than may admit the point of a needle. Or ſuppoſe it to have the wideneſs of a *Tobacco-pipe*, yet will the Mercury be ſuſpended, though the end be not drowned among ſtagnant *Quickſilver*, even as the Water P M, is kept up without ſtagnant Water about it. For trial of this, you muſt firſt let the end of the Pipe, be put down among ſtagnant Mercury, and after the Cylinder is fallen down to its own proper altitude, lift up the Pipe ſlowly, till the orifice come above the ſurface, and you will find, provided you do not ſhake the Pipe, the Cylinder to be ſuſpended after the ſame manner, immediatly by the Air, as the Water P M is.

EXPERIMENT VII.

Figure 10, 11.

TAke a Veſſel of any quantity, ſuch as A B C D E, and fill it with VVater, And a Glaſs-pipe, ſuch as G F D, of 15 or 20 inches long, of any wideneſs, cloſs above, and open below. Before you drown the open end among the VVater, hold the Glaſs before the fire, till it be pretty hot, and having put it down, you will ſee the VVater begin to creep up till it come to F, where it halts. The queſtion now is, what's the reaſon, why the VVater creeps up after this manner, 10 or 12 inches above the ſurface A B? I anſwer, the heat having rarified the Air within, and by this means, having expelled much of it, and the Air now contracting it ſelf again with cold, the

VVater aſcends, being preſt up with the weight of the incumbing Air, reſting upon the ſurface of Water A B. There is here ſurely an inequality between a *Pondus* and a *Potentia*, that muſt be the cauſe of this motion. I judge then the inequality to conſiſt between the weight of the Air within the Pipe, and the ſurface of Water C D E. To explicate this, I muſt ſuppoſe the Pipe to be thruſt down cold; in this caſe, little or no Water can enter the orifice D. And the reaſon is, becauſe the *Pondus* of the Air within the Glaſs, is equal to the *Potentia* of the ſurface C D E. But when the Pipe is thruſt down hot, much of the Air having been expelled by the heat, and now beginning to be contracted by cold, the *Pondus* of the Air becomes unequal to the *Potentia* of the ſurface, and therefore this, being the ſtronger party, drives up the Air within the Glaſs, till by this aſcent, the *Pondus* of the Air G F, and the *Pondus* of the Water F D together, become equal to the *Potentia* of the ſurface C D E, that ſuſtains them. For a ſecond trial; bring a hot coal near to the ſide of the Glaſs, between G and F, and you will find the Water to creep down from F toward the ſurface A B; and if it continue any ſpace, it will drive down the whole Water, and thruſt it out at D. To explicate this, I muſt ſuppoſe that heat, by rarifying the Air within the Glaſs, intends and increaſeth the *Benſil* of it, and the *Benſil* being now made ſtronger, there muſt ariſe an inequality between the *Pondus* of the ſaid Air, and the *Potentia* of the ſurface C D E; the Air then, being the ſtronger party, cauſeth the ſurface to yeeld.

By comparing this Experiment with the former, we ſee a great difference between the dilatation of Air, of its own accord, and by conſtraint. For while it is willingly expanded,

panded, the *Bensil* begins to grow ſlack, and remiſs, and loſeth by degrees of its ſtrength; even as the *Spring* of a *Watch* by the motion of the Wheels, becomes remiſs. But when the dilatation is made by heat, and the Air compelled to expand and open it ſelf, the *Bensil* becomes the ſtronger, and the Preſſure the greater. Notwithſtanding, though the *Bensil* of this incloſed Air G F, may be made ſtronger by heat, to the expulſion of the Water F D, yet if this rarefaction continue any time, the *Bensil* becomes dull and ſlack. And the reaſon is, becauſe Air cannot be expanded and opened to any quantity; an inch cannot be dilated and opened to an hundred, or to a thouſand: neither can the *Bensil* of it be intended, and increaſe to any degree, *v.g.* from one to 20, 30, or 100. And therefore, as the expanſion grows, the *Bensil* muſt at length ſlacken. But if ſo be the Air were incloſed, as in a bladder knit about the neck with a ſtring, then the more heat, the more *Bensil*: for in this caſe there is a growth of Preſſure, without dilatation. And ſometimes the *Bensil* may be ſo intended with the heat, that the ſides of the bladder will burſt aſunder.

From this Experiment we ſee firſt a confirmation of the 21 Theorem, namely, that there may be as much *Bensil* and Preſſure, in the ſmalleſt quantity of a Fluid, as in the greateſt; as is clear from the *Bensil* of the Air G F, which in effect counterpoiſeth the weight of the whole *Atmoſphere*, reſting upon the ſurface of Water A B. We ſee ſecondly, that when the *pondus*, and the *potentia* of two Fluids, are in *equilibrio*, or of equal ſtrength, a very ſmall addition to either of them, will caſt the ballance. For if a man ſhould but breath ſoftly upon the ſide of the Glaſs between G and F, or lay his warm hand to it, the ſaid Air will preſently dilate it ſelf, and by becoming thus ſtronger,

thruſt

thruſt down the Water, and ſo overcome the *potentia* of the ſurface. We ſee thirdly a confirmation of the ſixth Theorem, namely, that the Preſſure of Fluids is on every ſide; as is clear from the incloſed Air G F, that not only preſſeth down the Water F D, but with as great force preſſeth up the top of the Glaſs within, and preſſeth upon all the ſides of it within, with the ſame force. This Experiment alſo, leads us to the knowledge of two things: Firſt, of the reaſon, why with cold the Water aſcends in the common *Weather-glaſſes*; and why in hot weather the Water deſcends. Secondly, from this Experiment we may learn to know, when the Air is under a greater Preſſure, and when under a leſſer: becauſe when the Air becomes heavier, as in fair weather, the Water creeps up in ſome meaſure, it may be two or three inches; when there is no alteration as to heat and cold: and in foul weather, or in great winds, when the Air is really lighter, the ſaid Water creeps down as much. If it be asked, how ſhall I know, whether it be the cold of the Air, or heavineſs of the Air, that cauſeth the Water to aſcend; and whether it be the heat of the Air, or the lightneſs of the Air, that cauſeth the Water to deſcend? I have propoſed this queſtion of purpoſe, to let you ſee a miſtake. Many believe, that the aſcent and deſcent of Water in common *Weather-glaſſes*, is allanerly from the heat and coldneſs of the Air; and therefore they conclude a cold day to be, becauſe the Water is far up: whereas the Water hath aſcended ſince the laſt night, by reaſon of a greater weight in the Air, which alwayes is, when the weather is dry, and calm, though there hath been no alteration of heat to cold. If it be asked, how come we to the knowledge of this, that the preſſure and weight of the Element of Air, is ſome-

times

times leſs, and ſometimes more? I anſwer, this ſecret o Nature, was never diſcovered, till the invention of the *Torricellian Experiment*, otherwiſe called the *Baroſcope*. For after the falling down of the *Quick-ſilver* to 29 inches: if you ſuffer it to ſtand thus in your Parlour or Chamber, according as the Preſſure, and weight of the Element of Air, becomes more or leſs, ſo will the Altitude of the Mercury become leſs or more, and vary ſometimes above 29 inches, and ſometimes below. This alteration is very ſenſible, which is ſometimes the tenth part of an inch, ſometimes the ſixth, and ſometimes the third, according as the weight of the Air is leſs or more. From *December* to *February*, I found the alteration become leſs and more from 30 inches to 28, which will be three fingers breadth. The common *Weather-glaſſes* then are fallacious, and deceitful, unleſs they be ſo contrived, that the Preſſure of the Air cannot affect them, which is eaſily done by ſealing them *Hermetically*, and in ſtead of common Water, to put in *Spiritus Vini rectificatiſsimus*, or the moſt excellent Spirit of Wine, and ſtrongeſt that can be made.

It may be here inquired, whether or not, Mercury would aſcend in this Glaſs, as the Water does? I anſwer it would; becauſe the aſcent depends only upon the Preſſure of the Air, incumbing upon the ſtagnant Liquor in the Veſſell, that's able to drive up Mercury as well as Water. It may be inquired ſecondly, how far Mercury will aſcend, and how far Water will creep up? I anſwer, Mercury can aſcend no higher in a Tub, than 29 inches: and Water no higher, than 34 foot; and this onely happens, when there is no Air above the tops of the Cylinders to hinder their aſcents. But when there is Air, as G F above the liquor, it can go no higher, than the point to which the cold is

able

able to contract the inclosed Air, which is in this Glass, the point F. It may be inquired thirdly, which is the greater difficulty, whether or not Mercury, will rise as easily in a Tub as Water; for seeing, its 14 times heavier, it seemes the Air should have greater difficulty to press it up, than to press up Water? I answer, 'tis greater difficulty for the Air to press up 20 inches of Mercury, than to press up 20 inches of Water; yet its no greater difficulty, for the Air to press up 20 inches of Mercury, than to press up 23 foot of Water, because the burden and weight is the same. It may be inquired fourthly, whether or not, it be as easie for the Air, to press up a thick and gross Cylinder of Water, as to press up a thin and slender one? For example, whether is it as easie for the Air to press up a Cylinder of Water 10 inches in Diameter, and 10 foot high, as it is to press up one, two inches in diameter, and 10 foot high? I answer, there is no more difficulty in the one, than in the other: and the reason is, because Fluid bodies do not counterpoise one another according to their *thickness*, but only according to their *altitude*, according to the fourth Theorem. Therefore seeing the slender Cylinder is as high as the grosser, it must be no more difficult to the Air, to press up the one then the other.

There is one difficulty yet remaining, which is truely the greatest of all; namely what's the reason, why its more difficult to the Air, to press up 20 inches of Mercury, than to press up 20 inches of Water: or more difficult to the Air, to press up 20 inches of Mercury, than to press up 10? I answer, this comes to pass, because the Air is more burthened with 20 inches of Mercury, than with 10. Now, if this be, then surely it must be more hard to the Air, to do the one, than to do the other: even as it is more hard;

hard; for a man, to lift up from the ground, 20 pound of iron, than to lift up 10 or 15. The case may be better illustrated after this manner. Suppose a man standing on the ground, with a rope in his hand, coming down from a Pulley above, drawing up a weight to the top of the house: put the case likewise, the weight be a stone of 20 pound, and the weight of it, to increase successively, as it is pulled up. Now its easie for the man to pull up the stone the first fathom; because it is but 20 pound weight: but the stone becoming 40 pound in the second fathom, and 60 in the third, and 80 in the fourth and so forth, untill it become 1000, he will find the greater difficulty, the longer he pulls. 'Tis just so with Air, or Water, raising Mercury in a Tub; for as the Cylinder of the Mercury grows higher by rising, so it becomes heavier, and consequently the imaginary surface, upon which the *Base* of the Pillar rests, is more and more burdened, and so becomes less and less able to press it up. This leads us to a clear discovery of the reason, why 'tis more difficult by suction, to pull up Mercury in a Pipe, than to pull up Water; and more hard to suck up ten foot of Water, then to suck up five. For trial of this, which is soon done, take a slender Glass-pipe 30 or 40 inches long, open at both ends, and drown the one end among *Quick-silver*, and put your mouth to the other, and having sucked, you will find greater difficulty to pull up thorow the Pipe 15 inches of Mercury, than to pull up 10, or 8; and far greater difficulty to suck up 20, than to pull up 15. It may be objected, that if a man had strength sufficient in his Lungs, to suck out the whole Air of the Pipe, thirty inches of Mercury would come as easily up, as three, which seemes to prove, that the difficulty of the Mercurie's up-coming, depends not upon the weakness of

the Air,but upon the weakness of the Lungs, and want of strength to suck. I answer, though a man were able to suck out the whole Air of the Pipe, yet 30 inches, will never ascend so easily,as ten,nor ten so easily as three;and that for the reasons already given. But why is it then, (say you) that the stronger the suction be, the higher the Mercury ascends in the Pipe? I answer, the suction serves for no use, but to remove the impediment, that hinders the Mercury from coming up, which is nothing else, but the Air within the Pipe. Now, the more of this Air that's taken away by suction, (the stronger the suction is, the more Air is taken away) the farder up comes the Mercury. But why ought there to be difficulty in the suction of Mercury, to the altitude of 15 or 20 inches, more than in the suction of Water to that altitude? I answer, when I suck Water up thorow a Pipe, the suction of the Air above it, is easie; because the ascending Water helpes much to drive it up to the mouth, the outward Air driving up both. But the suction is difficult in Mercury, because the ascending liquor, does not help so much, to drive up the Air to the mouth, as the Water does. And the reason is, because the Air,being more burdened with 15 inches of Mercury, than with 15 inches of Water, cannot so easily drive up the one as the other, and so Mercury cannot so easily drive up the Air of the Pipe to the mouth, as Water does. In a word, according to the difference of *specifick* weight, between Water and Mercury, so is the difficulty of suction; therefore, because Mercury is 14 times heavier than Water,there is 14 times more difficulty, to pull up the one, than the other. Note, that *suction* is not taken here strictly, as contradistinguished from *pulsion*; but in a large sense, as it may comprehend it.

To

To proceed a little further, let us suppose the Pillar of Mercury (see the 11. Figure) G H, that's raised by the surface of Air F G, to be 29 inches, and every inch to weigh one ounce. Secondly, that the said surface has 29 degrees of power or force in it: for in all counterpoises the *Pondus* and the *Potentia* are equal; therefore, if the Mercury be 29 inches, the *Potentia* of the surface must have 29 degrees of strength or force in it, to counterballance the *Pondus*. These things being supposed, which are evident, let us imagine the surface of Air, to raise the Mercury one inch above F G. In this case, the surface is weaker than it was; which I prove evidently, because it is now but able to raise 28 of Mercury. Imagine next, the said surface to have raised the Mercury two inches above F G, then it follows, that it must be yet weaker, because it's now but able to raise 27 inches: for by supporting two ounce of the *Pondus*, it loseth two degrees of it's own *Potentia*. In raising three inches of Mercury, it is three degrees weaker; and in raising four, it is four degrees weaker, and so forth; therefore, having raised 28 inches, there is but one degree of force remaining in the surface. And when it hath raised the whole, namely 29, it is no more able, and can no more press. For confirmation, put the case that the surface of Air F G, were as able, and had as much Pressure in it, after it hath raised 29 inches of Mercury, as it is after the raising of 10; then it follows of necessity, that after the raising of 20, it shall raise 19 moe, which is impossible, seing the greatest altitude is 29. It follows of necessity, (I say) because after the raising of 10, it is able to raise 19 moe: therefore if it be as able after 20, as after 10, it must raise 19 after 20. Yea, if it be as able after 20 as 10, it must be as

able after 29 as 10. If this be, then it may raise other 29, and a third 29, and so *in infinitum*. Therefore, I conclude, that when two Fluid Bodies are in *equilibrio* one with another; or when the *pondus* is equal to the *potentia*, none of them doth actually press upon another, at least the surface hath lost all its Power and Pressure, which is also evident in the Pillar. For understanding this, let us suppose A C B (Figure 11.) to be a Pipe 58 inches long, and full of Mercury, and every inch of it to weigh one ounce. Now, when the orifice D is opened, there is here as great an inequality, between the *pondus* and the *potentia* of the surface of Air E B, on which it rests, as was between the surface F G, and the *pondus* of Mercury H G. For as F G had 29 degrees of power to raise G H, so the Pillar A B has 29 ounce of weight, to overcome the surface E B. And as the surface F G, became one degree weaker, by raising one inch of the Mercury H G, and two degrees weaker, by raising two inches, and so forward, till it lost all its Pressure; so the Pillar, by falling down one inch, loseth one ounce of the weight; by falling down two, it loseth two ounce, and so forward, till by falling down from A to C, it loseth all its Weight and Pressure.

But here occurreth a difficulty; for if the surface F G, hath lost all its Pressure, by raising the Mercury from G to H; and if the Pillar C B, hath lost all its Pressure, by falling down from A to C; it follows, that when a Pillar of a Fluid, and a surface of a Fluid are in equal termes, or brought to an *equipondium*, there is no Pressure in them at all. For answer, consider first, that in all counterpoises, there are necessarily two things, the *movens* and the *motum*, the thing that moves, and the thing that is moved. Secondly, you must consider the *motum*, to have a *pondus*

or

or weight in it, and the *movens* to have a *potentia*; or power, wherewith it moves that weight. Thirdly, that as the thing that moves, hath a power or force in it self, whereby it moves, so the thing that is moved hath a power or force in it self, whereby it resists the motion. Fourthly, that sometimes the resistance of the thing *moved*, may exceed the power of the *movent*, as when a Quarrier with a Leaver, endeavours to prize up a stone too heavy for him: or the power of the *movent*, may exceed the resistance of the *weight*; or both may be of equal power. Consider fifthly, that as the *pondus* of the thing moved, begins to grow more and more, so the power of the *movent* decreaseth proportionably; not absolutely, as heat is extinguished in Water by the cold Air, when it is removed from the Fire, but respectively. For example, when a man holds a ballance in his hand, with six pound in the one scale, and but one pound in the other, if you add another pound, the weight grows more, and the power and force of the opposite scale grows less proportionably; not *absolutely*, for it still remains six pound, but *respectively*: that's to say, six pound is less in respect of four, than in respect of five; or the resistance of six pound is less, two counterpoising it, than being counterpoised by one. When a third is added, the weight grows yet more, and consequently the resistance of the opposite scale becomes yet less, till by adding the sixth and last pound, you augment and encrease the *pondus* to that same degree of strength, that the resistance of the opposite scale is of. From these considerations, I say, the surface of Air F G, hath not lost all its Pressure *absolutely*, by raising the Mercury from G to H, but only *respectively*, because it still retains 29 degrees of force in it self. I say *respectively*, because when the Mercury is raised

raised ten inches, the power of the Air which is of 29 degrees of force, is less in respect of ten ounce, then in respect of five; or the power of 29 degrees of force is less, being counterpoised by ten ounce, than being counterpoised only by five. And when it is raised 20, it is yet less in this respect, than in respect of ten. And when it has raised the Mercury to the greatest altitude H, it may be said to have lost all its Pressure, seing it is not able, by vertue of a counterpoise, to do any more. Even as six pound in this scale, may be said to have lost all its resistance and weight, by putting in the other scale, first one pound, next two pound, and then three pound, till the last be put in, at which time it hath no more resistance. Though this be, yet it still remains six pound. Even so, the Air F G still remains of the same force and power, while it suspends the Mercury G H, that it was of before. Likewise, the Pillar A B, cannot be said to have lost all its pressure *absolutely*, by falling down from A to C, but only *respectively*, because the said Pillar C B, is still 29 ounce weight. I say *respectively*, because in falling down ten inches, or in losing ten ounce, the weight that's now but 48, is less, in respect of 29, than while it was 58. It is yet less, when it hath fallen down other ten, because being now but 38, it must be yet less in respect of 29, than 48. And when it hath fallen down to C 29, it may be said to have lost all its weight, because it can do no more, having *respectively* lost all its Pressure.

From what is said, we see a clear ground to distinguish in Fluids a *pondus* and a *potentia*. Secondly, that the *potentia* may sometimes exceed the *pondus*, and contrariwise the *pondus* may exceed the *potentia*. Thirdly, that inequality of weight, between the *pondus* and the *potentia*, is the

the cause of motion of Fluids. Fourthly, that the motion never ceaseth, till the *pondus* and the *potentia* become of equal force. This conclusion is not so universal as the rest, because the motion may sometimes cease, before this be. For example, when the Air is pressing Mercury up thorow a Tub shorter then 29 inches, the motion ends before there be a perfect counterpoise; for 20 or 15 inches of Mercury, can never counterballance the force and power of the Air. In such a case then, there is an unequal Pressure, the Air pressing the Mercury more, than the Mercury doth the Air.

EXPERIMENT VIII.

Figure 12.

TAke the Vessel A B C D, and fill it with Water, as high as H I. Take next a Cylinder of *stone* F G, and drowning the half of it among the Water, suspend it with a chord to the beam N O, with a ring at E. Now in this case, though the stone do not touch the bottom of the Vessel, yet the Water becomes heavier, than before. For discovering the true reason of this, I suppose first, the weight of the Water, before the *stone* be drowned, to be 40 pound. I suppose next, that after the *stone* is drowned, the said Water to weigh 50 pound. And lastly, the *stone* to weigh 60 pound. I say then, the Water must be 10 pound heavier than before, because it supports 10 pound of the *stone*. 'Tis certain the beam is less burdened by 10 pound than before. If this be, then surely the Water must sustain it. It were great temerity and rashness, to averr that neither the Beam, nor the Water sustains it,

which

which is really to say, it is sustained by nothing. It cannot be said without ignorance, that 10 pound of the *stone* is evanished, and turned into a *Chimera*. If it be said, how can such a Fluid Body as Water, be able to support any part of the weight of the *stone*, that is such a heavy Body? I answer, there is here no difficulty, for if the imaginary surface K L, upon which the 10 pound of the stone rests, be able to sustain 10 pound of Water (I suppose the *stone* taken away, and the place of it filled with Water) then surely it must also be able to sustain 10 pound of the heaviest metal; seing ten pound of Lead, or Gold, or Stone, is no heavier than 10 pound of VVater. If some say, this rather seems to be the reason, why the Water becomes heavier, after the *stone* is drowned, because it possesseth the place of as much Water, as would weigh 10 pound; not (as was said) because the VVater supports 10 pound of it. Therefore it may be judged, and thought, that if the space that the *stone* occupies, were filled with Air, or some light Body, without sensible weight, the VVater would become heavier than before. For example, if in stead of the *stone*, there were placed a *bladder* full of wind, within the VVater, and tied to the bottom with a string, that the surface might swell from H I to A B, the VVater of the Vessel would become as much heavier than before, as is the bulk of VVater, equal to the quantity of the *bladder*. Therefore, the VVater becomes heavier, not because it supports any part of the *stone*, but because the *stone* occupies as much room and space, as would contain 10 pound of VVater: for by this means the drowned *stone* raiseth the VVater from H I to A B; and so the Cylinders A C, and B D, being higher, press with greater weight upon the bottom C D, even with as much more weight,

as

as if the ſpace that the *ſtone* occupies were filled with VVater.

For anſwer to this, we ſhall make this following Experiment. Take the Veſſel M P V X, and fill it with VVater to Q R. Next, take a large *bladder* W Y full of wind, and tying the neck with a threed, thruſt it below the Water, and faſten it to the bottom, with a ſtring, to the Ring Z. This done, the Water ſwells, and riſes from Q R, to M P. Now, if it be true, that the Water in the Veſſel becomes heavier, not becauſe it ſupports 10 pound weight of the *ſtone*, but becauſe the *ſtone* occupies the room of 10 pound of Water; then it ought to follow, that after the *bladder* is tyed below the Water, the ſaid Water ſhould become heavier, than before, even by three pound; for I ſuppoſe a bulk of Water, equal to the bulk of the *bladder*, to weigh as much. And the reaſon is, becauſe (as you ſay) the quantity of the *bladder* W Y, makes the water ſwell from Q R to M P, by which means the Pillars of Water M V, and P X becomes higher, and ſo preſſeth with greater weight upon the bottom V X. For clearing this difficulty, I ſay, when a *bladder* is thus below the VVater, tyed to the bottom, the VVater becomes not three pound heavier: for when you place the Veſſel with the VVater and *bladder*, in the Scale of a Ballance, the ſaid VVater weighs no more, than if it wanted the *bladder*: therefore the VVater becomes not heavier, becauſe the *ſtone* poſſeſſeth the room of 10 pound of Water, but becauſe the Water ſuſtains 10 pound of the *ſtone*. Now the reaſon, why the *bladder* makes not the water heavier, though it raiſe it from Q R to M P, is this; becauſe though verily there be a greater Preſſure then before, even upon the bottom of the Veſſel, yet becauſe moe parts are not added,

the *natural weight* cannot be augmented, which essentially depends upon the addition of these parts. If it be replyed, the Experiment of the *bladder* is to no purpose, because it being knit to the bottom, pulls up the Vessel, with as great force, as the growth of the Pressure bears it down, and so the *Bladder* cannot make the Water heavier. But, if so be, it were possible, that the *Bladder* could remaine within the middle of the Water, without being knit to the bottom, and consequently without pulling up the Vessel, then surely the Pillars of Water M V, and P X, being higher, would press with greater weight upon the bottom, and so make the Vessel, and the Water weigh more in the ballance: for 'tis to be supposed, that during all this time, this Vessel with the Water, is in one scale, and a great weight of stone or lead, in the other. So would the Water A B C D become heavier likewise, provided the space and room, that the *stone* fills among the Water, remained intire, after the stone is taken away: because that room and empty space remaining, would keep the surface, as high as A B, by which means, the Pillars A C and B D, being higher, would press with greater weight upon the bottom, and cause the Water weigh more in the ballance. I answer, though by some extraordinary *power*, the *bladder* could remain below the water, of its own accord, as it were, and though the space and room, by that same *power*, which is left by the *stone*, were keeped empty, yet shall they never be able to make the Water heavier. As to the reason, that's brought, I answer, the rising and swelling of the Pillars, will make indeed a greater Pressure upon the bottom of the Vessel, but because this Pressure may be produced, and generated without the addition of new parts, therefore, it can never make the Water heavier: for if this

were

were true, then it would follow, that the more a body is compreſt, it ſhould be the heavier, which is contrary to ſenſe, and experience. This Preſſure is like unto *Benſil*, that cannot weigh in a ballance, though the *thing bended* do weigh; as a Bow that weighs ſo many pounds, but the *Benſil* of it weighs nothing: Next, will any man think, that a Cub of Water ſix foot high, and ſix foot thick, will weigh more in a ballance, then it did, after it is turned into a long ſquare Pillar 216 inches high? I grant, there is near 60 times a greater Preſſure, upon the bottom of the Veſſel, yet becauſe this Preſſure is generated, without the addition of new parts, it cannot make the Water heavier. Moreover, it is *mechanically* poſſible to keep the VVater S T V X, under that ſame degree of Preſſure it hath, though the reſt above were taken away: if this be, then it ought to be as heavy, as the whole, ſeing it ſtill Preſſes the bottom, with that ſame degree of Preſſure, it had from the whole: but what is more abſurd, than to ſay, one part of VVater, is as heavy, as the whole? *e. g.* a pint as heavy as a gallon. If it be ſaid, the Preſſure, and the weight, are but one thing, at leaſt *effectively*, which is ſufficient to the purpoſe in hand, as is clear from the Theorem 23. I anſwer, they are but one thing indeed, in order to the *Ballance of Nature*, but they are neither *formally*, nor *effectively* the ſame thing in order to the *Libra* or *Artificial Ballance*, whereof we are now treating. I ſhall conclude with this; while the Veſſel with the VVater, is thus placed in the Scale of the Ballance, and in *equilibrio*, with the oppoſite Scale, cut the ſtring that tyes the *bladder* to the bottom, and when it comes above, you will find the VVater, juſt of the ſame weight it was of: for though the ſurface M P, by taking out the *bladder*, ſettle down to Q R, yet there's

no alteration made in the weight. From this I gather, that if the ſwelling of the VVater ſhould make it heavier, then the ſubſiding and falling down of it, ought to make it lighter.

From theſe Experiments we gather firſt, that in VVater there is a Preſſure, becauſe it ſuſtains 10 pound of the *ſtone* F G. Secondly, that whatever heavy body is weighed in Water, it loſeth juſt as much of its weight, as the bulk of Water weighs, it puts out of its place. This is evident, becauſe the *ſtone* is 10 pound lighter in VVater, than in the Air, becauſe the VVater that would fill the room of the *ſtone*, is juſt of that weight. VVe ſee thirdly, that the *Preſſure* of VVater, and the *natural weight* of it, are two things really diſtinct; becauſe the *Preſſure* may be augmented, without any increment of the *natural weight*. VVe ſee fourthly, that the *Preſſure*, or *Benſil* of a Fluid, cannot affect the Scale of a Ballance, but only the *natural weight*. VVe ſee fifthly, that a body naturally heavier than Water, *weighs in Water*, becauſe the *ſtone* F G, makes the Water about it, 10 pound heavier. If it be inquired, whether bodies, that are naturally lighter, will *weigh in Water*? I anſwer, if they be of any ſenſible weight, they weigh, as well as the other. For this cauſe, I except Air. For though they were never ſo light, in reſpect of Water, yet if they have any conſiderable gravity with them, they will make the Water heavier, they are among. Put the caſe the Body were a Cube of Timber of ſix inches, weighing ſixteen ounces, and that a Cube of Water of that quantity, weighed 112 ounces. Here's a great inequality, between their *natural weights*: yet if that piece of Timber, were made to exiſt in the middle of Water, as the *Bladder* doth, it would make it 16 ounces heavier.

The

The reason is this; these 16 ounces are either supported by a surface of Water, or they support themselves. This last is impossible. If the VVater support them; then must they make the said VVater 16 ounces heavier. Note, that though a Body naturally lighter then VVater, as *Cork*, may be said to *weigh in Water*, that's to say, to make it heavier, in which sense VVater *weighs in Water*, because if you add a pint to a gallon, it makes it heavier; yet if you take a piece of *Cork*, and knit it to the Scale of a Ballance, by a threed, the *Cork* hanging among the VVater, the Scale hanging above in the Air, it will not *weigh in Water*; because in this sense, no Body *weighs in Water*, but that which is naturally heavier then VVater, as Lead, or Stone. In this sense, VVater doth not *weigh in Water*, as will be seen in the 17 Experiment.

EXPERIMENT IX.
Figure 13.

Take a Glass-pipe 70 inches long or there-about, and of any wideness, having the upper end H, *hermetically* sealed, the *lower* end C compleatly open, and fill it with Mercury, and cause a *Diver* carry it down to the ground of the sea M N, where I suppose is standing the Vessel A B D E with stagnant Mercury, and drown the end below the surface A B. This being done, the Mercury falls from the upper end H, to the point G, and there halts; the space H G being empty. For understanding this Experiment, I shall propose several questions, and answere them. First, what's the reason, why the Mercury subsides, and sinks down from H to G? I answer, as formerly

merly in the like cases, inequality of weight between the *Pondus* of the impending *Quick-silver*, and the *Potentia* of the surface, of the stagnant *Quick-silver* D C E. For while the Tub is compleatly full, the weight is so great, that the surface D C E, is not able to sustain it, therefore it must fall down, seing motion necessarily followes in Fluids, upon inequality of weight. It may be inquired secondly, why it halts at G, 58 inches from A B, and comes no further down? I answer it halts at G, because when it hath fallen down to that point, there happens equality of weight, between the suspended Pillar, and the foresaid surface: for whatever weight the said Pillar is of, the surface on which it rests, is of the same. In a word, the *Pondus* of the one, and the *Potentia* of the other are now equal. For understanding this, consider according to the 25 Theorem, that the weight of the Element of Air, upon the surfaces of waters, is equivalent to the burden of 34 foot of water, therefore the first and visible surface of this Water L I K, is really as much prest, with the burden of the *Atmosphere*, as if it had 34 foot of Water upon it. Consider next, that between the said surface, and the ground M N, are 34 foot of Water indeed. Consider thirdly, that a Pillar of Water 34 foot high, is exactly of the same weight, with a Pillar of Mercury 29 inches high; for if Water be 14 times lighter than Mercury, then they cannot be of equal weight, unless the one be 14 times higher than the other. Now, supposing the weight of the Air upon the surface L I K, to be equivalent to 34 foot of Water, or (which is the same thing) to 29 inches of Mercury, the surface of the stagnant Mercury A B, must be as much burdened with the incumbing Water, and the Air together, as if it had really resting upon it, a Pillar of

Mercury

Mercury 58 inches high. If this be, then it follows by necessity, that there must be an equality of weight, between the *pondus* of the Mercury in the Tub, and the *potentia* of the surface D C E; Or (which is all one thing) that the part C, on which the Pillar rests, is no more burdened, than the part D or E. For if 34 foot of Water, and 34 foot of Water, be equivalent for weight, to 58 inches of Mercury, then must the part D and E, be as much burdened with the said weight, as the part C is burdened with the Pillar within the Tub; seing both are of the same height: therefore the power, and force of the imaginary surface of the stagnant Mercury D C E, is of the same strength, with the weight of the Pillar G F B. And this lets us see the reason, why the whole 70 inches cannot be suspended; for if the outward Pressure that's upon A B, be but equivalent to the Pressure of 58, it can never make the surface D C E able to support 70.

To make it evident (if any doubt) that the Mercury is suspended by the weight of the Water, and the weight of the Air superadded, let a *Diver* bring up this Engine to the top of the Water, and he will find the one half to have fallen down, namely from G to F, the other half F B remaining. And if it were possible, to convey this Experiment to the top of the Air, the Bearer would see, the remaining half to fall down likewise, and become level with A B; for where no Pressure of Air is, there can be no Mercury suspended. This falling down, is not all at once, but by degrees, and keeps a proportion with the Pressure of the Air, that grows less and less, from the ground to the top.

From this Experiment we see first, the great Pressure and weight, the Elements of Air and Water are under, seing

ſeing this Water, that's but 34 foot deep, ſuſtains the Mercury between G and F, 29 inches, as much between F and E, being kept up by the Preſſure of the Air. We ſee ſecondly, that this Preſſure is according to *Arithmetical Progreſsion*, as 1, 2, 3, 4, 5. becauſe in going down the firſt 14 inches, the Mercury riſes one inch; in going down the ſecond 14 inches, it riſes two; in going down the third 14 inches, it riſes three, and ſo forward. We ſee thirdly, though a VVater were 100 fathom deep, yea 1000, yet the Preſſure of the Air above is found at the bottom: for ſuppoſing this Experiment were 100 fathom deep, yet would the Air from above have influence upon it, to ſuſtain ſo many inches of the Mercurial Cylinder. A *Diver* then, 10 or 15 fathom under the VVater, muſt be burdened with the weight of the Air, as well as with the weight of the VVater, ſo muſt the Fiſhes, though never ſo deep. We ſee fourthly, that the parts of a Fluid cannot ceaſe from motion, ſo long as there is an inequality of weight between the *pondus* and the *potentia*. This is clear from the falling down of the Mercury from H to G. And aſſoon as equality of weight happens, the motion ends. This is clear from the Mercurie's halting at G. Fifthly, that in Mercury, as well as in Water, or Air, ſurfaces may be diſtinguiſhed, and that theſe ſurfaces, are endowed with a *Potentia* or power, begotten in them by ſuperior and extrinſick weight. This is clear from the imaginary ſurface D C E, that's made powerful to ſupport 58 inches of Mercury in the Tub, and that by the weight and Preſſure of the Air reſting upon A B. Sixthly, that, as two Fluids differ in *ſpecifick* and natural weight, ſo they differ in *altitude*, when they counterpoiſe one another. This is clear from the diſproportion that's between the altitude

titude of the Mercury fuſpended, and the height of the Water, and Air ſuſpending. G F then is 29 inches, and the deepneſs of the Water from K to N is 34 foot,becauſe Water is naturally 14 times lighter than Mercury. F B is likewiſe 29 inches, and the hight of the Air, that reſts upon the ſurface of Water is ſix or ſeven thouſand fathom high; becauſe Air is 14000 times *naturally* lighter than Mercury. Seventhly, that Fluid Bodies counterpoiſe one another, not according to their *thickneſs* and *breadth*, but only according to their *altitude*. This is evident; for though this Tub were never ſo wide or narrow, yet the altitude of the Mercury is unchangeable. Hence it is, that the *thickeſt* Pillar of Water in the Ocean, is not able to ſuſpend more Mercury, than the *ſlendereſt*, I mean as to altitude. And hence it is, that the ſmalleſt Cylinder of Mercury, no thicker than a ſilk threed, is able to counterpoiſe a Pillar of Water, of any thickneſs whatſoever. We may conclude laſtly, that when a *Diver* is 20 fathom under the Water, he is under as much burden, as if he were under 14 or 15 foot of Quick-ſilver. Suppoſe a man lying on his belly, within a large Veſſel, and 14 or 15 foot of Mercury poured in upon him, ſurely it may be thought, that ſuch a burden were inſupportable. But put the caſe, the *Diver* were down 40 fathom, then muſt the burden be doubled. This follows, becauſe if a Pillar of Water 34 foot high, with the weight of the Air ſuperadded, be as heavy, as 58 inches of Mercury, then ſurely a Pillar 20 fathom high, or 100 foot, muſt be as heavy as 170 inches, which is more than 14 foot.

EXPERIMENT X.
Figure 14.

AGainst the former Experiment, there occurres some difficulties, which must be answered. As first, if it be the Pressure of the Water, that sustains the Mercury in the Tub (see the 13. Figure) then the weight of the said Mercury ought not to be found, while the Tub is poised between a mans Fingers. But so it is, that when a *Diver* grips the Tub about the middle, and raises it a little from the bottom of the Vessel, he not only finds the weight of the Tub it self, but the weight also of the 58 inches of Mercury that's within it. But this ought not to be, if the said Mercury, be sustained by the outward Water. In a word, it ought not to be found, because the said Pillar of Mercury, as really stands, and rests upon the imaginary surface D C E, as a Cylinder of Brass or Stone, rests upon a plain Table of Timber or Stone. If then, it be supported by the said surface, why ought I to find the weight of it, when I lift up the Pipe a little from the bottom of the Vessel? For clearing this difficulty, consider, that when the Mercury falls down from H to G, it leaves a sort of *vacuity* behind it, wherein there is neither Air nor Water. Consider secondly, that for this cause, there happens an unequal Pressure; the top of the Tub without, being burdened with the Pillar of Water I H, which actually presseth it down, and nothing within between G and H, that may counterballance that downward Pressure. These things being considered, I answer to the difficulty and say, it is not the weight of the suspended Mercury that I find, but the weight of the Pillar of Water I H, that rests upon

on the top of the Tub. If it be said, the Pressure of a Fluid is *insensible*, and cannot be found. I answer, it's true, when the Pressure is equal and uniform, but not when the Pressure is unequal, as here. If it be asked, how comes it to pass, that the Pillar of Water I H, is exactly the weight of the 58 inches of Mercury? I answer, besides the said Pillar, there is another of Air, that rests upon the top of it, which two together are exactly the weight of the suspended Mercury; I H being of the same weight with the Mercury G F, and the foresaid Pillar of Air, being of the same weight with the Mercury F B. To make it more evident, remember that one inch of Mercury, is exactly the weight of 14 inches of Water; and that one inch of Mercury, is of the same weight with 14000 inches of Air. If this be, then must the Pillar of VVater I H, that's 34 foot high, and of the same thickness with the 29 inches of Mercury G F, be of the same weight with it, seing 29 inches are to be found 14 times in 34 foot. For the same reason, is the Pillar of Air, namely S I, that rests upon the top of the Pillar of VVater I H, of the same weight with the 29 inches of Mercury F B. For after a just reckoning, you will find, that 29 inches will be found 14000 times in the Pillar of Air, that rests upon the Pillar I H. Or in a word, the hight of the Air is 14000 times, 29 inches.

But here occurrs another difficulty. Let us suppose there were a Tub six foot high, one inch wide, having the sides, 3 inches thick. Imagine likewise the said Tub to be under the water 34 foot, with 58 inches of Mercury in it, as is represented in this 14. Figure. This being supposed, the Pillar of Water E A F C G D, must be far heavier, than the 58 inches of Mercury H B. The reason is clear,

because the said Pillar, is not only 34 foot high, but as thick, as the Diameter of the Tub, whose sides are three inches thick. I answer, the whole weight of that Water E A F C G D is not found, while a man poises the Tub between his fingers, but only the weight of the part G A, which is exactly the weight of the Mercury H B. But here occurrs the great question, namely, why I find only the weight of the Water G A, and nothing of the weight of the Water, C E, or D F? I answer, I cannot find the Pressure of the Water C E, because it is counterpoised with the upward Pressure of the Water I K. And for the same reason, I cannot find the weight of the Water D F, because it is counterpoised by L M; but because there is nothing between H and A, to counterpoise the downward Pressure of the Water G A, therefore I find that. If it be objected, that the Water I K, cannot counterpoise the Water C E, because the one is farder down than the other, and consequently under a greater Pressure, than the other. I answer, though I K be stronger than C E, yet a compensation is made by the weight of the Tub. For understanding this, let us suppose the Water C E, and D F, to press downward with the weight of six pound, and the Water K I, and L M, to press upward with the weight of ten pound, there being four pound in difference. Suppose next, the Tub to weigh in the Air ten pound, and in the Water only six pound. If this be, then according to the eighth Experiment, and eighteenth Theorem, four pound weight of the Tub must rest upon the surface I L. And if this be, then must the Water I K, and L M, be four pound weaker with the Tub, than without it, and must only have six pound of upward Pressure.

From

Fig. 9 *Pag. 59*

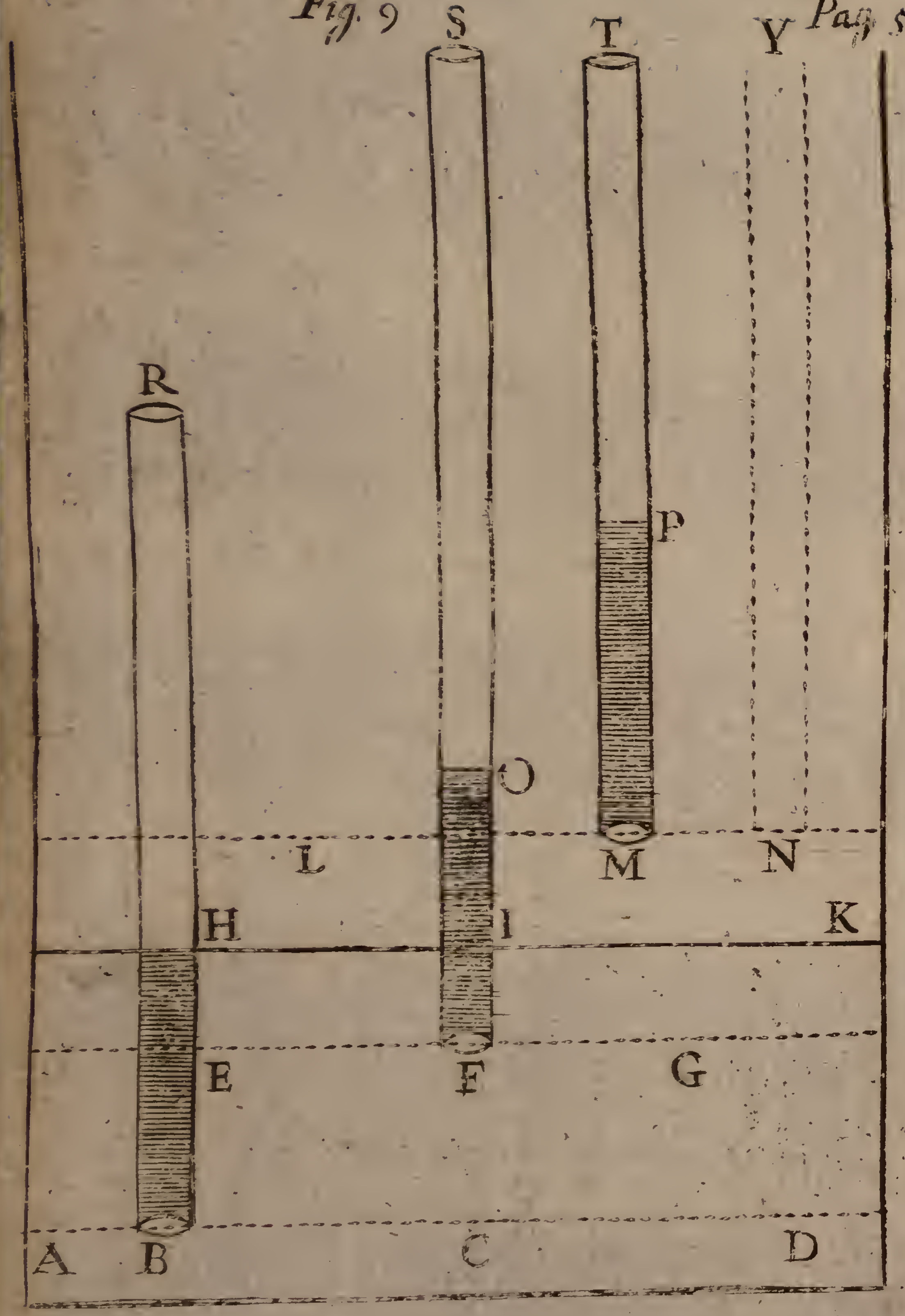


Fig. 10

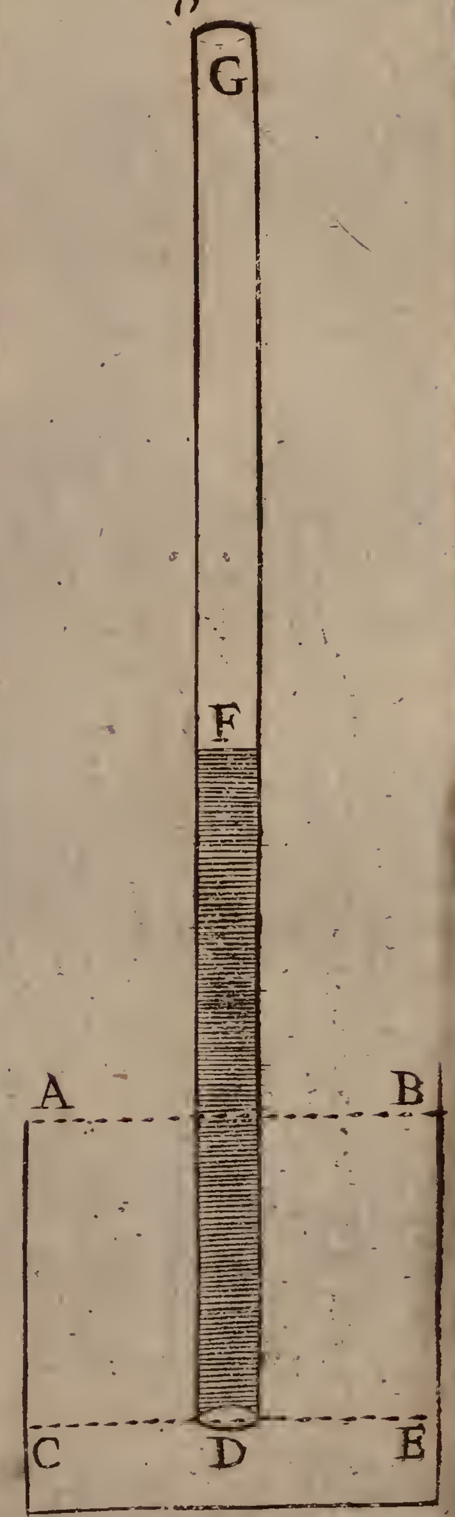


Fig. 11 *Pag. 71*

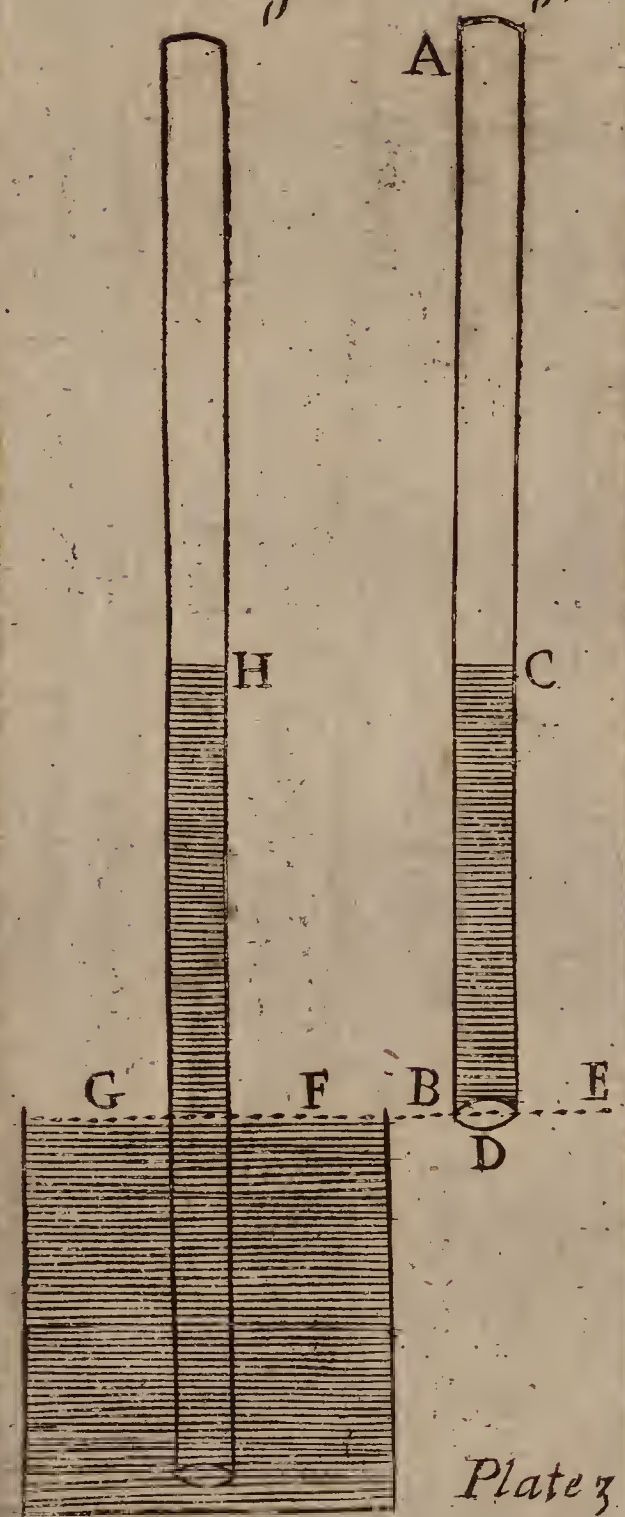


Plate 3

Fig. 13 *Pag. 81*

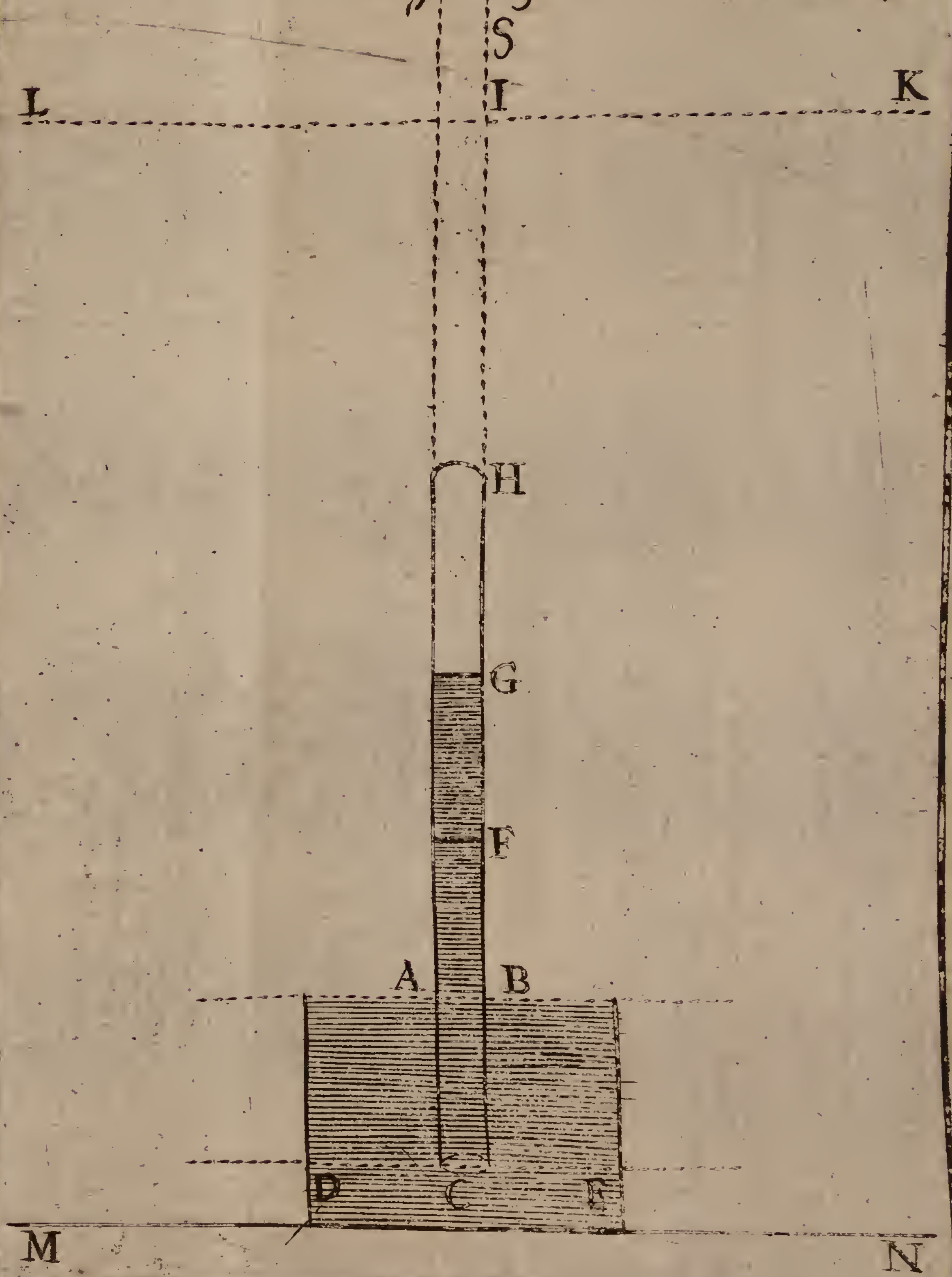
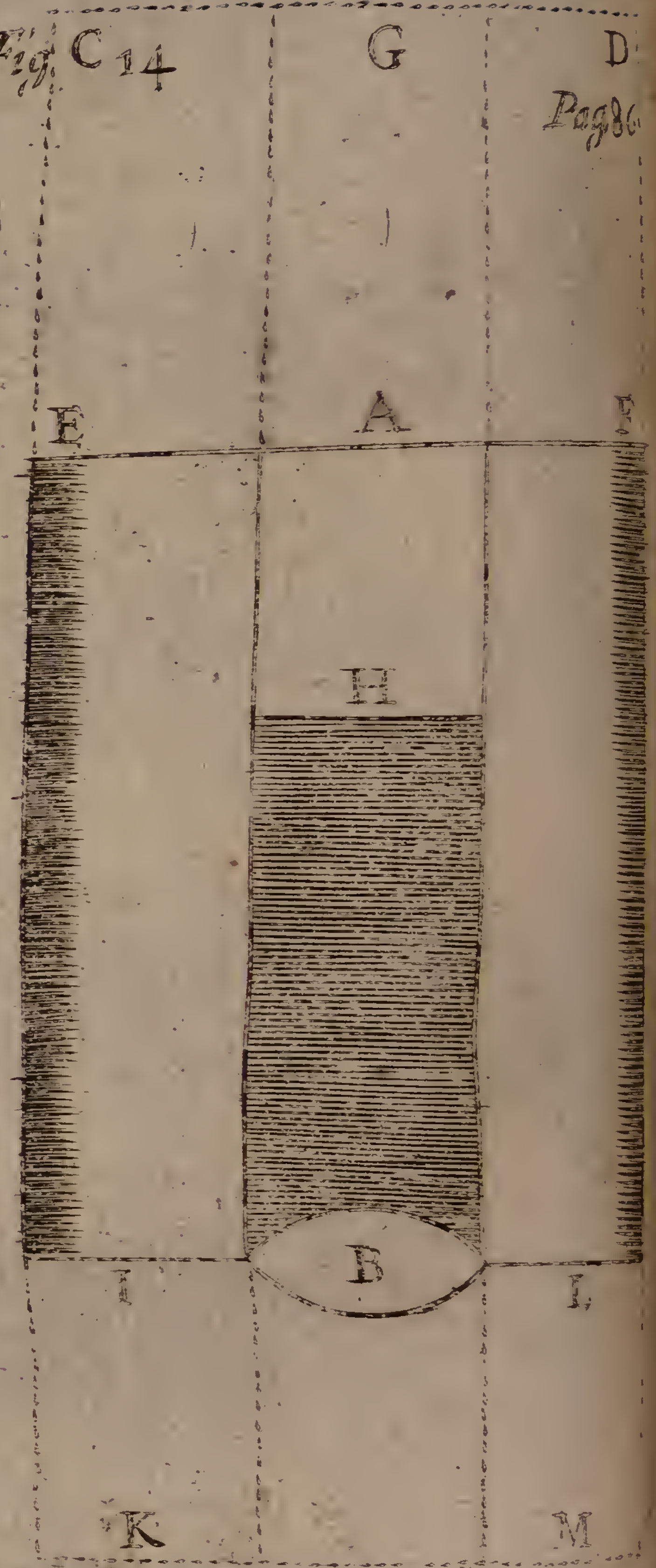


Fig. 14 *Pag. 86*



From these Experiments we conclude first, the truth of the tenth Theorem, namely that the weight of a Fluid is only found by sense, when the Pressure is not uniform, and equal. This is evident from our finding the weight of the Pillar of Water I H, as in the 13 Figure. We conclude secondly, that in all Fluids, there is a *pondus* and a *potentia*; as is clear from the *pondus* of Water E A F C G D, that presseth down the Tub, and the *potentia* of the Water I K L M, that presseth up the same Tub. We see thirdly, that there cannot be two surfaces of Water differing in altitude, but they must differ in degrees of Pressure: because the surface E A F, is weaker, than the surface I L, that being higher than this. We see fourthly, that two surfaces differing in strength, may be made equal by some Body or other interveening; because, though I L be stronger than E A F, yet seing it supports four pound of the Tub, it presseth up with no more force, than E A F, presseth down with. We see fifthly, that a Body suspended in a Fluid, as in Air, or in VVater, may have one part of it prest equally with that Fluid, and another part unequally: this is evident, because the parts E and F, are equally prest with the Pillars C E, and D F, seing this Pressure is counterpoised with the Pressure of VVater, I K, and L M. But the middle part of the Tub A, is unequally prest, seing it is prest downward, with the VVater G A, but not prest upward with the Mercury B H. VVe see sixthly, that whatever be the thickness of a Pillar of a Fluid; yet no more of its weight is found, or is sensible, than the part, which presseth unequally: for though E A F C G D, be a Pillar six or seven inches thick, yet no more of the Pressure is sensible, than what comes from

G A.

G A. VVe ſee ſeventhly, that a Body equally preſt with a Fluid, weighs leſs, but a Body unequally preſt, weighs none at all. This is clear in many particulars; for a Stone weighed in VVater, loſeth not all the weight, but a part, becauſe it is equally preſſed. But a Body unequally preſt, as is the Mercury H B, hath no weight at all, as it now ſtands. For underſtanding this, you muſt conſider, that the whole weight of it reſts upon the ſurface of VVater I L. Therefore though it could be weighed by a ſtring, paſſing from the top H, to a Ballance exiſting in the Air; yet the ſaid Ballance would find none of its weight, ſeing it is wholly ſuſpended by the VVater; but a Stone ſo weighed, is only ſuſpended in part, by the Water.

EXPERIMENT XI.

Figure 15.

A M Z C is a Water 15 foot deep. A B a Glaſs-tub 14 inches long, and full of Mercury. B C a Pillar of Water 13 foot, 10 inches high, thorow whoſe middle goes a ſtring to the ſcale of the Ballance K, exiſting in the Air. D E is a Tub full of Mercury 28 inches long, with a Pillar of Water above it E F, 12 foot and eight inches. G H a Tub 42 inches long, with a Pillar of Water above it H I, 11 foot and ſix inches high. And laſtly, A D G S M an imaginary ſurface, 15 foot deep. This Experiment is brought hither, to demonſtrate that a heavy Body, weighs as much in Water, as in Air, which is point-blank to the common received opinion, and deſtructive of the 18 Theorem. To evince this, I muſt ſuppoſe the 14 inches

inches of Mercury in the Tub A B to weigh 14 ounce; and the 28 inches of Mercury D E, to weigh 28 ounce; the 42 inches G H to weigh (I mean in the Air) 42 ounce. Now I say, to make a just *equipondium* between the two Scales K and L, there must be 14 ounce put into the Scale L. If after this manner you weigh the Tub and Mercury D E, 28 ounces will be required in the Scale L, and 42, if you weigh the Tub and Mercury G H. For proving this Doctrine, I must appeal to Experience, which will not fail in this. If you reply, and say, upon supposition the Tub and Mercury G H, were a solid piece of brass, or iron thus suspended in the Water, ought it not to weigh less here than in the Air, even as much less, as is the weight of the quantity of Water, it puts out of its place: why then should not the Pipe H G, with the Mercury in it, do the same, seing there is no apparent difference between them, as to this?

But to leave this, which will appear afterwards, and to let the Reader see the truth of the 18 Theorem, I affirm, 'tis not the weight of the 14 ounces of Mercury A B, that burdens the scale of the Ballance K, and that makes a counterpoise with the 14 ounces of Stone, or Lead, thats in the scale L. What then is it, you say? I answer, 'tis 14 ounces of the Pillar of Water B C that does this. Neither doth the weight of the 28 ounces of Mercury D E burden the Ballance, but only 28 ounces of the Water E F. Neither doth the Ballance support the weight of the 42 ounces of Mercury G H, but it is only burdened with 42 ounces of the Water H I. The reason is most evident, because according to the Principles of the *Hydrostaticks* already laid down, the Cylinder of Mercury A B, within the Tub A B, rests immediatly upon the imaginary sur-

face

face of the Water A D G, and therefore cannot burden the ſcale in any wiſe. The ſame is true of the other two Cylinders of Mercury. But in this I find ſmall difficulty. The greater is, how to make it out, that the ſcale K, ſupports 14 ounces of the Water B C, and 28 of the Water E F, and 42 of the Water H I. To make this ſeem probable, conſider firſt, as was noted, that this VVater is 15 foot deep, and conſequently the Pillar of VVater B C, 13 foot 10 inches. The VVater E F 12 foot eight inches. And H I, 11 foot and a half. Conſider ſecondly, though this be true, yet we muſt count the Pillar of VVater Z M 49 foot high. The reaſon is evident, becauſe the Preſſure of the Air, upon the ſurface of all Waters (according to the 25 Theorem) is equivalent to 34 foot of Water: this then being added to 15, makes 49, and by this reckoning the Water B C is 47 foot ten inches: the Water E F 46 foot eight inches: And laſtly, the Water H I 45 foot ſix inches. Thirdly, for eaſie counting, I muſt ſuppoſe the whole Cylinder Z M to weigh 42 ounces, every 14 inches one ounce: and conſequently the Water B C to weigh 41 ounces; the Water E F to weigh 40 ounces; the Water H I 39 ounces. Note, that in *Phyſical* demonſtrations, 'tis not needful to uſe *Mathematical* ſtrictneſs in counting; and ſo leaving out fractions, we ſhall onely uſe round numbers. Conſider fourthly, that in all Fluids, as hath been frequently marked, there is a *pondus* and *potentia*, the Water B C being the *pondus*, and the Mercury A B the *potentia*, the one ſtriving to preſs down the Tub, the other ſtriving to preſs it up. Conſider fifthly, that by how much the more a Body ſuſpended in a Fluid is preſſed up, by ſo much the leſs the weight that preſſeth it down is found: and contrariwiſe,

trariwiſe,by how much the leſs it is preſſed up, by ſo much the more the Preſſure above is found. Conſider ſixthly, the leſs that a ſurface of Water is burdened, the more able it is to counterballance the oppoſite Preſſure, and the more it is burdened,it is the leſs able. Conſider ſeventhly, that the Mercury A B, (which is evident in all Fluids) not only preſſeth downward , and burdens the ſurface A D G, but alſo preſſeth upward, and therefore actually endeavours to thruſt up the Tub; and ſo it is, that the Tub is preſſed between two, namely between the Water C B, and the Mercury within it.

Now from theſe conſiderations I ſay, the ſcale K, muſt ſupport,and bear up 14 ounce of the Water B C : for ſeing the Mercury is ſupported by the ſurface of VVater on which it reſts , it cannot by any means burden the ballance with its weight ; and ſeing it actually preſſeth up the Tub , (according to the ſeventh conſideration) it muſt ſo much the more counterpoiſe (according to the ſixth) the oppoſite Preſſure of the VVater B C, and conſequently diminiſh the weight of it : ſo that the Ballance cannot ſupport the whole, but a part. For according to what degrees of force, the Mercury preſſeth up the Tub with, according to the ſame, muſt the Preſſure upon the top of the Tub be diminiſhed, and ſo if the Mercury preſs up the Tub with the force of 27 ounce , the VVater B C muſt preſs it down with 14 ounce only, and ſo the Cylinder B C, that weighs really 41 ounce, muſt preſs the top of this Tub only with 14, which 14 ounce really counterpoiſeth, the 14 ounce of Stone in the Scale L. But how is it made out, that the Mercury A B, preſſeth up with 27 ounce? For underſtanding this, remember, that the VVater is 49 foot high, taking in the Preſſure of the Air, and that a

VVater of that deepnefs is able to fupport 41 inches of Mercury, every inch weighing one ounce. For if 14 of Water, be able to fupport one of Mercury, 49 foot, or 567 inches, muft fupport 41. If then, the part of the furface A, be able to weigh 41, it muft have of upward Preffure 27 ounces, feing it's counterpoifed *de facto* only with 14. Take notice, that in the *Hydroftaticks*, the word *preffing*, or *weighing*, as really and truly fignifies a weighing up, as a weighing down, feing it is no lefs effential to Fluid Bodies to move upward, than downward, and that with equal force, and weight. According to this reafoning, the Ballance fupports 28 ounces of the Water E F, (Imagine the fecond Tub to be fufpended as the firft) feing the Cylinder of Mercury D E, preffeth up the Tub only with the weight of 12 ounce, which 28 ounce, really counterpoifeth the 28 ounce of Stone in the Scale L. But why doth the Mercury A B prefs up with 27 ounce, and the Mercury D E with 12? For anfwer, remember, (according to the fixth confideration) the fhorter a Cylinder of Mercury is, the furface upon which it refts, is the ftronger, and more able to prefs it up; and contrariwife, the longer it is, the furface is the more unable and weak: therefore A B being fhorter, and lighter than D E, the furface of Water muft prefs it up with greater force: fo that if the faid furface A M, be able to prefs up the Mercury A B with 27 ounce, it muft prefs up the Mercury D E only with 12 ounce. According to this rule, if the Mercury A B were 15 inches high, it would prefs up only with 26 ounce, if it were 16, with 25: if 17, with 24: if 18, with 23, and fo forward. This leads us to a clear difcovery of all the fecrets here: for if the Mercury A B, thruft up the Pipe, with the weight of 27 ounce, then

muft

must the Scale K, be eased of so much weight, and so much must be subtracted from L. Now let us imagine the Pipe A B, to be empty both of Air, Water, and Mercury: in this case 41 ounce must be in the Scale L, to counterpoise it, seing the whole Cylinder B C, that weighs so much, does now really counterpoise it. Let us imagine next, these 14 inches of Mercury to rise, and fill the Tub A B: in this case, there happens a great alteration; because the rising of them, are really equivalent to the subtracting of 27 ounce from the Scale L; and the reason is, because by so rising and filling the Tub, they thrust up the said Tub, and by this means easeth the Scale K, of so much weight. Now this Scale being eased, you must of necessity take out from L 27 ounce for making a new counterpoise.

And lastly, the Scale K must support the whole weight of the Water H I, which is 39 ounce, nothing remaining to counterballance this downward Pressure, and consequently to ease the Ballance. How then is it counterpoised? For clearing this, you must remember that this Water, that's really 15 foot deep, must be reckoned (as I said) 49, because of the Pressure of the Air upon the top, that's equivalent to 34. If then it be so, it cannot raise Mercury higher in a Tub than 42 inches; the one being 14 times heavier than the other: so that if 14 inches of Water, cannot raise Mercury higher than one inch, 49 foot cannot raise it higher, than 42 inches: for as 14 inches, are to one inch; so is 49 foot to three foot and an half, which is 42 inches. Now I say, the whole weight of the Water H I, rests upon the top of the Tub, and so presseth down the Scale K, to which you must imagine this Tub, knit by a string, as the former was, nothing remaining to

counterpoiſe this downward Preſſure: for the top of the Mercurial Cylinder being raiſed as high within the Pipe, as the ſurface of Water D G S, is able to raiſe it, the ſaid top can impreſs no force upon the Tub within, to thruſt it up, and ſo to eaſe the Scale K. For example, when a man erects upon his hand a Cylinder of Timber, or any ſuch like thing, which is the outmoſt he can ſupport, he will not be able to impreſs any impulſe, upon the ſeiling of a room above his head; but if ſo be, in ſtead of that taken away, there be one lighter erected, which he is able to command, he can eaſily thruſt up the ſeiling at his pleaſure. Juſt ſo it is here; for the 42 inches of Mercury, being the outmoſt, that the ſurface of Water D G S is able to bear, it cannot impreſs any impulſe therewith upon the top of the Tub within: but eaſily can the Cylinder D E impreſs an impulſe, and more eaſily the Cylinder A B, ſeing they are lighter, and ſo more powerful. To evidence this a little more, let us imagine two things, firſt, the Tub G H to be empty, as if *vacuity* were in it. In this caſe the top of the Tub ought to bear the whole burden of the Water, and conſequently the Ballance to bear it alſo: becauſe there is not a *potentia* within the Tub, to counterpoiſe this *pondus*. Next, let us imagine the Tub to be only full of Water: according to this ſuppoſition, the Ballance cannot be in the leaſt part burdened; becauſe the Water within the Pipe, preſſeth it up with as much force, as the Water I H preſſeth it down: and if any thing ſhould burden the Ballance, it would be only the weight of the Pipe, that's not conſiderable.

From what is demonſtrated, we ſee firſt, that though this Experiment would ſeem to prove at the firſt, that a heavy Body weighs as much in the Water, as it doth in the

Air,

Air, because the whole weight of the Mercury A B is found in the scale L, yet 'tis not so; because the 14 ounce of Stone L, doth not counterpoise any of the Mercury AB, but 14 ounce of the Pillar of Water BC. Secondly, there's here a clear ground, for asserting a *pondus* and a *potentia* in Fluids; because this Tub A B, is prest down with the VVater B C, and prest up with the Mercury within it. Thirdly, there's here a clear ground for asserting the Pressure of VVater, even in its own place; because the Water B C, counterpoises by it's weight, the 14 ounce of Stone L. Fourthly, we see an excellent way for finding the weight of any Cylinder of Water; for whatever be the weight of the Mercury in the Tub, the Cylinder of Water, that rests upon the top, will be of the same weight exactly; this is evident in comparing the weight of the Mercury G H, with the weight of the Water H I. Fifthly, that whatever be the height, and weight of a Pillar of Water, yet the Ballance can sustain no more of it, than the just weight of the Mercury: this is also evident, because the scale of the Ballance, supports no more of the weight of the Water B C, than the just weight of the Mercury A B. We see sixthly, the further down a Pipe with Mercury goes through Water, the greater is the Pressure it makes upon the top of the Tub within: for put the case, this were 100 foot deep, the Mercury G H, that wants all upward Pressure now, would press up the Tub with 40 ounce: the Mercury D E with 55, and the Mercury A B with 70. We see seventhly, the shorter a Cylinder of Mercury be, it is the stronger in pressing; and longer it be, it is the weaker; for there's more strength in A B, than in D E. We see eighthly, that the strength decayes, and grows, according to *Arithmetical progression*, as 1, 2, 3, 4; because

if

if you make the Cylinder G H 41, that's now 42, it presseth up with one ounce. Make it 40 inches, it will press up with two ounces of weight. Make it 39, it presseth up with three. And contrariwise, make the Cylinder D E 29 inches, that's now but 28, it will press up with 11 ounce only. (VVith 28 it presseth up with 12.) Make it 30 inches high, it will press up with 10. If it be 31 inches, it presseth up with nine, and so forward. Lastly, make the Cylinder A B 15 inches, that's now but 14, it presseth up with 26 (with 14, it presseth up with 27) make it 16, it presseth up with 25; make it 17, it presseth up with 24. We see ninthly, that in Fluids, we may make a distinction between a *sustentation*, and an *equipondium*. 'Tis evident here, because there's a perfect *equipondium* between the 42 inches of Mercury G H, and the outward Water that's 49 foot deep. But 'tis not so, between the said Water, and the Mercury D E; because the said Water is able to raise the said Mercury 14 inches higher: therefore the Water only *sustains* the Mercury D E, but *counterballances* the Mercury G H. We see tenthly, that the *pondus* of the pillar of Water B C is counterpoised by two distinct *powers* really. The one is the 14 ounce of Stone in the scale L, the other is the 14 inches of Mercury A B, that as really thrusts up the Water, as the scale K pulls it up, by vertue of the opposite weight. Eleventhly, take away the Stone L, and you will find the Pipe with the Mercury A B sink down: this happens, not because the surface of Water on which it rests is not able to sustain it, but because the 14 ounce of the Water B C, that was supported by the Stone, doth now press it down. Twelfthly, the more a Body is unequally pressed by a Fluid, the more of the weight of that Fluid is sensible; and the

more.

more equally a Body is presfed, the lefs fenfible is the weight of that Fluid: this is evident, becaufe there's a greater weight of the VVater H I found in the Ballance (it takes 42 ounce to counterpoife it) than of the VVater E F, which is counterpoifed with 28 ounce: and the reafon is; becaufe the top of the Tub H, fupports the whole 39 ounce of VVater H I, the Mercury within the Tub, not being able in the leaft to counterpoife it, or thruft it up. But becaufe the Tub D E, is more equally preffed (the VVater E F preffeth down with 40, and the Mercury D E preffeth up with 12) therefore lefs weight of the VVater E F burdens the Ballance, only 28 ounce. Hence it is, that becaufe the Tub A B, is more equally preffed, than either D E or G H, there's lefs of the weight of the VVater B C, found in the Ballance, only 14 ounce. Thirteenthly, if in the inftant of time, while the Tubs are thus fufpended in the VVater, the Preffure of the Air above were taken away, and *annihilated*; then firft, the 42 inches of Mercury G H would fall down, to about 13 inches. Secondly, the 28 inches of Mercury D E, would fall down to as many. And laftly, the 14 A B, would fink down to the fame height. The reafon is, becaufe the Preffure of the Air being equivalent to 34 foot of VVater, no more would remain but 15 foot, which is the real height, according to Z M. But 15 foot of Water, cannot fuftain moe inches of Mercury than about 13. And confequently, firft, 14 ounce of Stone in the Ballance, would counterpoife the whole Water B C. The reafon is, becaufe the Water B C is but of 14 ounce; and the Mercury A B, being but 13 inches high, could imprefs no impulfe upon the top of the Tub within, that's 14 inches high. Secondly, 13 ounce of Stone in the Scale L, would coun-

counterpoise the whole Water E F, seing E F is but 13 ounce. Thirdly, the same weight (one ounce being deduced) would counterpoise the Water H I, because in this case, it weighs but 12 ounce,

To proceed a little further, imagine the Pipe G H to be suspended by the ballance, as the Pipe A B is; and then a little hole opened in the top H, to suffer the Water to come in, till the Mercury subside 14 inches, namely from Q to O (imagine this Tub to be the other) and then stop it. The reason why the VVater rusheth in, and presseth down the Mercury, is the force and Pressure of it: for the said VVater, finding the Cylinder in *equilibrio* with the outward VVater, presently by its own weight, casts the scales, which is easily done, seeing the surface G S M supports as much burden as it can. But that which is more considerable is this; after the subsiding of the Mercury from Q to O; the *equilibrium* that was between the scale of the ballance, and the VVater QR is destroyed: for whereas 42 ounces were required before; 29 will now do it. For understanding the reason of this, consider that between Q and O, are 14 inches of VVater rushed in, which are equivalent to one inch of Mercury. Next, according to former reasonings, the ballance must support 29 ounces of the VVater Q R; because in this case, the top of the Pipe within, is pressed up with the weight of 13 ounces; which in effect, diminisheth as much of the downward Pressure of the VVater R Q, which before had the burden of 39 ounces. But why is the Tub prest up with 13 ounces? I answer, because the Mercury, that before was 42 inches, is now but 28: or having the 14 inches of Water Q O above it, it is 29, therefore being shorter, the surface G S M is the more able to Press it up, even with as much more force, as it is in inches shorter. In

In the second place, let in as much Water more, as will depreſs the Mercury other 14 inches, namely from O to P. In this caſe, 16 ounce of ſtone will make an *equipondium*; becauſe, the 14 inches of Mercury P S, and the 28 inches of Water P O Q, being a far lighter burden by 26, than the 42 inches of Mercury, the ſurface G S M muſt be far abler to preſs them up now, than before: and therefore, muſt diminiſh as much of the downward Preſſure of the VVater Q R, that burdens the Ballance, as themſelves wants of weight: ſeing then, the whole Cylinder of Mercury, and Water together, are but equivalent for weight to 16 inches of Mercury, the top of the Tub within, muſt be preſt up with 26 ounce; and therefore they by their upward Preſſure, muſt diminiſh 26 ounce of the weight of the Water R Q, that weighs 39. Laſtly, let in ſo much VVater, as will depreſs the laſt 14 inches P S; and you will find no more weight required in the Ballance to make an *equipondium*, than counterpoiſeth the ſimple weight of the Tub, which is not conſiderable. The reaſon is, becauſe, the part S, of the ſurface G S M, being liberated of the burden of Mercury, and ſuſtaining only the VVater within the Tub, in ſtead of it, this ſurface preſſeth up the VVater within the Tub, and conſequently the top of it, with as great force, and weight, as the top of the Tub without is depreſſed, with the outward VVater R Q: therefore, 39 ounce depreſſing the Tub, and 39 ounce preſſing it up, the Ballance muſt be freed of the whole weight of VVater R Q. If it be objected, that the 42 inches of VVater Q S, are equivalent in weight to three inches of Mercury; therefore the part of the ſurface S, being burdened with this, cannot preſs up, with as great force, as the VVater R Q preſſeth down. For anſwer, conſider, that the part S, is able to

N ſupport

ſupport 42 ounce of VVater, and next, that the VVater R Q weighs but 39. Then I ſay, ſeing the 42 inches of VVater within the Tub, weighs only three ounce, the part S, that's burdened therewith, being able to ſupport 42, it muſt preſs up with the weight of 39, and ſo counterballance the VVater R Q.

If it be inquired, whether or not, would the 14 inches of Mercury A B fall down, a ſmall hole being made in the top of the Tub at B? I anſwer, they would. If it be objected, that theſe 14 inches of Mercury, are not in *equilibrio*, with the Preſſure of the ambient Water, as the Mercury GH, and therefore they cannot be ſo eaſily depreſſed by the Water, that comes in at the ſaid hole. I anſwer, they muſt all fall down, and as eaſily, as the other, and that becauſe of inequality of weight between the *Potentia* of the ſurface of VVater, and the *Pondus*. It's certain, the part A of the ſurface, cannot ſupport more weight of any kind, than 42 ounce; but when a hole is opened in B; and the VVater comes in, 'tis then burdened with the weight of 14 ounce of Mercury, and with the weight of 41 ounce of VVater; ſo much the VVater B C weighs, which is 55 ounce: but a ſurface that hath only the *Potentia* of 42, can never ſupport a *Pondus* of 55, no not of 43.

It may be objected thus: Put the caſe a Cylinder of Gold, or Braſs were ſuſpended in this VVater; as the Pipe and Mercury G H are ſuſpended by the Ballance, would not the Ballance ſupport the whole weight of it, without ſupporting any part of the weight of the VVater I H, that reſts upon the top of it. I anſwer, there's a great difference between the two; becauſe a Cylinder of Gold or Braſs, ſuffers both the upward and downward Preſſure of the VVater; but the Mercury G H, ſuffers

only

only the upward Preſſure, being freed of the downward, by the top of the Tub. From this Experiment of letting in the VVater upon the top of the Mercury, we ſee firſt, that when two Fluids are in *equilibrio* one with another, a very ſmall weight will caſt and turn the Scales, becauſe, if the ſixth part of an inch of VVater come in at Q, it preſently alters the hight of the Mercury from 42 inches to leſs. Secondly, 'tis impoſſible for a ſurface of Water, to ſupport more weight, than its own proper burden; becauſe the part S, cannot ſupport more, no not a grain, than 42 ounce. VVe ſee thirdly, that it is as impoſſible for a ſurface of VVater, to ſupport leſs, than its own burden; becauſe whatever loſs of weight the Pillar of Mercury S Q ſuffers, by the ingreſs of the VVater Q O, its made up again by the ſame VVater. If it be objected, that the 14 inches of VVater QO, are not ſo heavy by far, as the 14 inches of Mercury, that fell down. I anſwer, its true, yet the part S, is as much burdened as before, becauſe what is wanting in weight, its made up, and compenſed by Preſſure. VVe ſee fourthly, that the *Preſſure* of a Fluid is a thing really diſtinct from the *natural weight*, according to the 22 Theorem: becauſe though the 14 inches of Water QO, are not ſo heavy naturally as the 14 inches of Mercury that fell down, yet the Preſſure of them upon the ſurface S, is as much. We ſee fifthly, that 14 inches of Water, that's a body fourteen times lighter than Mercury, may have as much weight with them, as 14 ounce of Mercury. We ſee ſixthly, that a Cylinder of Mercury cannot be ſuſpended in Air, or in Water unleſs it be guarded with a Tub, to preſerve it from the downward Preſſure of that Air or Water: for by opening an hole in Q, the Mercury ſubſides. We ſee ſeventhly, that 'tis impoſſible for two Fluids to ſuſpend

one another mutually, unless there be a sort of *equipondium* between them; because no sooner you destroy the *equipondium*, between the 42 inches of Mercury QS, and the part of the surface S, by the ingress of the Water QO, but assoon there ariseth a new one. We see eighthly (as we noted before) the nearer a Body comes to be equally pressed with a Fluid, the less is the Presure of that Fluid *sensible*: because less weight is required in the Ballance, to counterpoise the Presure, and weight of the Water R Q, after the ingress of the Water Q O P, than after the ingress of the Water QO. We see ninthly, that when a Body is equally, and uniformly pressed with a Fluid, the Pressure is *insensible*; because, after the Water hath thrust down all the Mercury from Q to S, there's no more weight at all of the Water R Q found in the Ballance. We see tenthly, that not only in Water, the Pressure of Water may be found, but out of it, namely in the Air; as is clear from the Ballance, that supports the Pressure of the Water R Q. We see eleventhly, a ground to distinguish between the *natural Ballance*, and the *artificial Ballance*. The *artificial Ballance*, is the Ballance K L: the *natural*, is the Pipe QS. We see twelfthly, that they keep a correspondence between themselves, or some *Analogy*: for by what proportion the Water thrusts down the Mercury, by that same proportion the *pondus* L, of the Ballance is lessened: and by what proportion the Mercury rises in the Pipe, by that same, is the weight L augmented in the Scale. We may subjoyn lastly, that the easiest way of explicating the *Phenomena* of Nature, is not always the best, and truest. For some may think, it were far easier to say, that the Ballance supports the Mercury AB, or D E, and not any part of the Water B C, or E F. But such a way would be false, and absurd, and contrary to all the former Doctrine.

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EXPERIMENT XII.
Figure 16.

THis Schematism represents a Water 100 foot deep, whose first and visible surface is I H K. And L M is the ground of it. C D is a piece of *brass* 30 inches high, and 12 inches in diameter, suspended upon the imaginary surface of Water A N B, which is distant from the top I H K, 25 foot. This *Brass* cannot go farder down, when demitted from H; because it's keeped up, by the Force and Pressure of the surface of Water A N B, which I prove thus. The part B sustains *de facto*, a Pillar of Water K B 1400 pound weight: therefore the part N is able to sustain as much. I suppose here, the said piece of *Brass* to weigh 1400 pound. The Water K B is 1400 pound, because its a Pillar 25 foot high, and 12 inches thick, for one cubical foot weighs 56 pound Trois. The *connexion* of the argument is evident, because it is as easie for a surface of Water, to sustain a solid Body, as to sustain a Fluid Body: therefore, if the part B, support the Fluid Pillar K B, the part N must be able to support likewise the solid Pillar C D, which is of the same weight. If it be objected, that the part N, sustains besides the *Brass* C D, a Pillar of Water E F 22 foot high, and a half, which two will weigh 2260 pound. I answer, upon supposition, that neither Water nor Air succeeded, the space E F being void of both, the *Brass* would be suspended with the force and power of the Water N. And though this cannot be made *practicable*, yet the *Theory* of it may conduce much for explicating the secrets and mysteries of the *Hydrostaticks*. But why ought the *Brass* to be suspended

pended at 25 foot from the top? I answer, because the *potentia* of the surface A N B, is equal to the *pondus* of the *Brass*. To evidence this, consider that *Brass* is a Body *naturally* heavier then Water; I shall suppose ten times, that's to say, one inch of *Brass* will counterpoise ten inches of Water. If this inequality be, then must this Pillar of *Brass* go so much farder down, than the first surface I H K, as the one is heavier *in specie*, or *naturally*, than the other: therefore it must sink 25 foot exactly; seing a piece of *Brass* 30 inches high, requires 400 inches of Water, or 25 foot to counterpoise it: for if one inch of *Brass* require ten inches of Water, then surely 30 inches must require 300. Yet it is no matter, what the thickness be, provided it be no higher than 30 inches.

To advance some farder, let us make a second supposition, namely, while the *Brass* is thus suspended upon the surface A N B, suppose the Air to come down, and fill up the imaginary space E F, then must the *Brass* be thrust down as far as the surface O P, that's 34 foot below the surface A N D, and 59 from the top. The reason of it is this, because the weight of the Air superadded, is equivalent to the Pressure of a Pillar of Mercury 29 inches high, and 12 inches thick: therefore the *Brass* being burdened with this, it must go so farder down, till it meet with a surface, whose *potentia* is equal in weight, to the *pondus* of both, which is precisely 59 foot from the top: for if one inch of Mercury require 14 of Water, then 29 inches must require 405 inches, or 34 foot. In a word, it must go as far down, as that surface, that sustains a Pillar of Water, that would counterpoise in a Ballance, the *Brass* C D, and a Pillar of Mercury 29 inches high, and 12 inches thick, both which weighs 3290 pound.

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From what is said, we see first, that of two heavy bodies differing in weight, the lighter may go farther down than the heavier. This is clear, because a slender *Cylinder* of *Gold*, in form of an Arrow, half an inch thick, and 28 inches long, weighing 28 pound ('tis no matter, though the just weight of it be not determined) will go down 35 foot in Water, before it meet with a surface, whose *potentia* is equal in weight to its own *pondus*; for if *Gold* be 15 times heavier *naturally* than Water, then the said Cylinder must go down before it rest, 420 inches, or 35 foot. But a piece of *Gold* 12 inches long, and six inches thick, that perhaps will weigh 208 pound, will sink no further than 15 foot. And the reason is, because, if one inch of Gold require 15 of Water to counterpoise it, then 12 must only require 180, or 15 foot. Note, that both the bodies must go down *Perpendicularly*, and not as it were *Horizontally*, with their sides downmost: for if they go down after this manner, they cannot sink so far. The reason of this is also evident, because a heavy body goes so far down, and no further, till it hath thrust as much Water out of its place, as will counterpoise it self in a Ballance. That's to say, if an heavy body weigh 100 pound, it must go no further down, than after it hath thrust out 100 pound of Water. But so it is, that a piece of Gold, in form of an Arrow, going down *side-wise*, or with the two ends parallel to the Horizon, will thrust as much Water out of its place, as will be the weight of it self, before it can go down 15 or 16 inches from the top: because for every inch it goes down side-wise, it expells 28 inches of Water. In going down two inches, it expells 56. In going down three inches, it expells 84, and so forward, till it go down 15 inches, where it expells 420 inches: but

but 420 inches amounts to 35 foot. Now, take a Cylinder of Water 35 foot high, and just the thicknefs of the Cylinder of Gold, which I suppofed to be of half an inch, and put them in a ballance, and you will find the one just the weight of the other. Neither can the piece of Gold go fo far down as before, if it go down *fide-wife*; becaufe for every fix inches it is drowned, it expells a bulk of Water 12 inches long, and fix inches thick; therefore it muft be fufpended, before it go beyond 90 inches, or feven foot and an half: now, if fix inches give one foot, 90 inches will give 15 foot: but 15 of Water in hight, and fix inches thick, is the juft weight of it in a ballance, *viz.* 208 pound. We fee fecondly, the broader and larger the furface of a Fluid be, 'tis the more able and ftrong to fupport an heavy burden: therefore the part of a furface of Water fix inches fquare every way, will carry a far greater weight, than a part four inches fquare. Though a furface of Water 34 or 35 foot deep, be not able to fuftain a Cylinder of *Gold*. if it exceed 28 or 29 inches in hight, yet take a Cylinder of *Gold*, 10 foot high, and reduce it, by making it thicker, to the hight of 20 inches, a furface of Water little more than 24 foot deep will fuftain it. Or reduce a Cylinder 10 foot high, which requires a furface more than 100 foot deep, to a Cylinder fix inches high, a furface little more than feven foot deep will fupport it. We fee thirdly, the reafon why bodies that are broad and large, move flowlier through Air and VVater, than bodies that are more thin, and flender, though both be of the fame weight in a ballance. For example, 20 pound of Lead, long and flender like an Arrow, will go fooner to the ground of a deep VVater, than a piece of Lead of the fame weight, in form of a Platter or Bafon. The reafon is, becaufe as the body

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is broader, ſo it takes a broader part of a ſurface, which broader part is ſtronger and abler, than a narrower part, and ſo makes the greater reſiſtance. The ſame is the reaſon, why a Bullet ſix inches in Diameter, moves ſlowlier thorow the Air, ſhot from a Cannon, than a Bullet one inch in Diameter. For the ſame reaſon, Ships of ſeven or eight hundred Tun, move far ſlowlier thorow the Air, and Water, than Veſſels of leſs burden. Item, large and big Fowls, as Eagles, move ſlowlier, than ſmall Birds, as Swallows. Yea, of Fowls of the ſame quantity, one may move quicklier than another, as is evident in long-wing'd *Hawks*, as *Falcons*, that by the ſharpneſs of their Wings, move far more ſpace in half an hour, than Kites, or Goſe-Hawks, whoſe wings are rounder. We ſee fourthly, that there's no body how heavy ſoever, but it may be ſupported by the ſurface of a Fluid, either in Air or in VVater. I grant, the ſtrongeſt ſurface of Air, that can be had, is not able to ſupport more weight, than a Cylinder of *Gold* 28 inches high: yet though it were as large, and broad, as a *Mill-ſtone*, if it do not exceed the ſaid hight, the Air is able to ſuſtain it. For the ſame cauſe, if it were poſſible to free a *Mill-ſtone* of the Air, that reſts upon it, the Air below would lift it from the ground, and carry it up many fathoms, even till it came to a ſurface, equal in power to the weight of the Stone: Or, if a large *Mill-ſtone* were demitted from the top of the *Atmoſphere*, towards the *Earth*, it could hardly touch the ground, being detained by the way, by a ſurface counterpoiſing it. Or if it did touch, through the ſwiftneſs of the motion, it would ſurely, as it were, rebound, and be carried up again. It is alwayes to be remembred, that in ſuch trials, the Air is ſuppoſed not to follow, or to be united, after the Stone

passeth thorow. Now if the Air be able to do this, far more the VVater, that's a body a thousand times heavier. We see fifthly the reason, why heavy bodies move so easily thorow Air, and Water, namely because the parts that were divided, by the body that is moved, are presently reunited, and closed again, by which means it is driven forward, the Pressure upon the back, being as much as the Pressure before. If this were not, no body whatsoever would be able to move it self one foot forward. For example, if, when a man hath advanced one step forward, the Air did not close again upon his back, the force of the Air upon his belly and breast, would not only stop him, but violently thrust him backward. We see sixthly, the reason, why the same body descends with more difficulty thorow Water, than Air, because a surface of Water is far stronger, than a surface of Air. We see seventhly, that a heavy body is never suspended by a surface of Water, or Air, in going down, till once it hath displaced, as much Water or Air, as will counterpoise it self in a ballance. This is clear from the *Brass* C D, that goes alwayes down, till it expell its own weight of Water. For this cause, if a *Mill-stone* were demitted, or sent down from the top of the Air, and never rested, till it came within 40 fathom of the *Earth*, then so much Air, as is expelled by the descent, is the just weight of the stone. We see eighthly, the heavier a body be *naturally*, than Water, it goes the further down, and the lighter it is, it sinks the less. For if C D were of Gold, it would go further down, than being of Brass or Iron: and if C D were a stone, that's lighter *in specie* than Brass, it would not go so far down. This lets us know the reason, why thicker, blacker, and heavier clouds comes nearer to the *Earth*,

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than thinner, whiter, and lighter. VVe see ninthly, that the Pressure of the Air is determinable, even in its heighest degree, and seemes to be the same in all places of the world; but the Pressure of the Water is not so. The reason of the first part is, because the Element of Air seems to be of the same hight in all places, and therefore we may know its outmost Pressure, which is just equivalent to the weight of 28 or 29 inches of Gold, or Mercury. But because the deepness of the Sea is variable, therefore the Pressure is variable likewise. Yet if the exact deepness, of the deepest place were known, it were as easie to determine the greatest Pressure of it, as to determine the greatest Pressure of the Air. We see tenthly, that a very small weight added or subtracted in height, will change and alter the counterpoise of a Fluid. Because if you lay but one ounce upon the top of the *brass* at F, it presently subsides accordingly: or take one ounce from it, and it rises. But though never so much weight be added to it, or subtracted from it in thickness, no alteration follows. Therefore, though this piece of *Brass* C D, that's now but 12 inches in thickness, were made 24, by which means the weight would be tripled and more, yet the same surface A N B would sustain it: yet, add to it in altitude, but one inch, and presently it sinks down proportionably. This evidently discovers the reason, why its as easie for the Air, to support a Cylinder of Mercury 3 inches thick, as to support a Cylinder half an inch thick: and why it cannot support more in height than 29 inches, and why it cannot support less. Now the reason, why a thicker Pillar, is as easily suspended, as a thinner, is this, because if a Pillar of Mercury be thicker, and consequently heavier, than it takes a broader, and consequently a stronger surface of Air to rest

upon: if it be but slender, and so but light, then it takes a lesser part of a surface to bear it up, and consequently a weaker; by which means the *Pondus* of the one, is alwayes proportionable to the *Potentia* of the other. Is it not as easie for a Pillar of stone, 6 foot in Diameter, to support another six foot in Diameter; as it is for a Pillar one foot in Diameter, to support a Pillar one foot in Diameter? But as a Pillar one foot in Diameter, cannot support a Pillar 6 foot in Diameter, neither can a surface of Air, one inch in Diameter, support a Pillar of Mercury 6 inches in Diameter. But why should a larger part of a surface be stronger than a narrower part? I answer, the one is stronger than the other, for that same reason, why a thicker Cylinder is heavier than a thinner: for what I call *strength* in a surface, its nothing else but *weight*, and what I call *weight* in a Cylinder, its nothing else but *strength*. The same thing hath two names; because the pillar of a Fluid presseth down, and the surface supports: therefore, in the one its called *pondus*, in the other *potentia*. As when two scales are in *equilibrio*, either this, or that may be called the *pondus*; or either this, or that, may be called the *potentia*. Now I say, if a part of a surface four inches broad, have as much weight or force in it, as a Pillar of Mercury four inches thick; then surely, a part of a surface eight inches broad, must have as much weight and force in it, as a Pillar of Mercury eight inches thick. But why ought a surface to succumb, when the Pillar grows in hight, and not to fail when it grows only in breadth? *Ans.* VVhen it grows in breadth, the *pondus* never exceeds the *potentia*; but when it becomes higher, then it becomes heavier. That's to say, when a Pillar grows broader, there's not one part of the surface that sustains it, more burdened than another;

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ſeing the part eight inches broad, is no more preſt with a Pillar eight inches thick; than the part four inches broad, is preſt with a Pillar four inches thick: as eight ounce of Lead in this Scale, is no more counterpoiſed with eight ounce in the other Scale, than four ounce in this Scale, is counterpoiſed with four in the other. But when a Cylinder grows in hight, the *pondus* exceeds the *potentia*; one part of a ſurface being more burdened than another. We ſee eleventhly, that in a large ſurface of a Fluid, wherein are many parts; each part is able to ſuſtain its own proper burden. So a part eight inches in Diameter ſupports a Pillar eight inches thick; and a part four inches, ſupports a Cylinder four inches thick; but cannot ſupport a Pillar ſix inches thick. But this ſeems rather to flow from the *diſproportion* of *Magnitudes*, ſeing a circular plain 4 inches in diameter, cannot receive a Baſe of a Pillar 6 inches in diameter. But this is certain from the very nature of Fluids, that in a deep VVater, wherein may be diſtinguiſhed 100, or 1000 different ſurfaces, each one is able to ſupport his own burden, and no more.

EXPERIMENT XIII.

Figure 17, 18, 19.

FOr making this Experiment, take two *plain* Bodies of Braſs, or Marble well poliſhed. Make them of any quantity; but for this preſent uſe, let each of them be four inches broad ſquare-wiſe. Upon the back part, let each one have an handle about ſix inches long, of the ſame metal, formed with the *plain* it ſelf, in the founding (if they be of Braſs) as is repreſented in this Schematiſm. When they

they are thus prepared, anoint their inner-sides with Oyl or Water, and having thrust the one face alongst upon the other, with all the strength you have, till all the four edges agree, two whereof are represented by A B, and C D, you will find them cleave so closs together, as if they were but one Body. The effect is this, that ordinary strength will not pull them asunder; and that under a surface of Water, a stronger pull is required than in the Air.

That we may deduce some *Hydrostatical* conclusions from this Experiment, let us suppose these two *plain* Bodies to be united in the middle of the VVater I K P Q, that's 34 foot deep, and suspended by a beam or long tree T V existing in the Air, near the top of the VVater, by a chord S E passing between the middle of the beam, and the end of the handle at E. Suppose next a great weight of Lead R, 350 pound, to be appended to the end of the handle at H, of the under *plain* Body C D N O. This done, I affirm, that the beam T V, neither sustains the under *plain* Body C D N O G H, nor the 350 pound weight of Lead R, that hangs down from the handle G H. If it be objected, that the beam supports the upper *plain* Body A B L M F E; therefore it must bear the weight also of the under *plain* C D N O G H, with the weight R; seing they are both united together, and cleave so closs, as if they were but one Body. I answer, it supports the one unquestionably, but not the other. To explicate this *Hydrostatical* Mystery, I must aver three things; first, that the inferior *plain* is supported by the upward Pressure of the lower VVater P Q N O. Secondly, that the burden which the beam sustains, is not the weight of the under *plain*, but the weight of the 34 foot of Water I K L M. Thirdly, that this weight is exactly the weight of

of the inferior *plain*, and Lead R. But is it not more easie to say, that the beam supports both the *plains*? I answer, if I say so, I can neither affirm truth, nor speak consequentially. But may it not be said, that the inferior *plain* is supported both by the beam, and the lower water P Q N O? I answer, this is impossible; because one and the same weight, cannot be supported totally, by two distinct supporters.

For making these assertions evident, I must suppose the superior Water I K L M to be 34 foot deep, and to weigh, if it were put into a ballance, 400 pound: and which is unquestionable, that the said Water rests upon the back of the superior *plain* L M. I suppose secondly, that the lower Water P Q N O weighs as much, and thrusts up the inferior *plain* with as great weight, as the superior *plain* is prest down with, by the superior Water. This is evident from former Experiments. And lastly, I suppose each *plain* to weigh two pound, and the weight of Lead R 350. It is to be observed here, that no mistake may arise in the calculation afterwards, that though it be said, this 34 foot of Water weighs 400 pound, yet in it self it weighs but 200: but considering the Pressure of the Air upon I K, which is as much, it may be truly said to weigh 400. These things being premitted, I say the weight that the beam T V sustains, is not the weight of the inferior *plain*, and the Lead R, but 352 pound of the superior VVater I K L M, and consequently, that the inferior *plain* is supported by the lower VVater P Q N O. The reason is, because the lower VVater presseth up with the weight of 48 pound. It is in it self 400 pound: but being burdened with 352, it cannot thrust up with more weight than 48. Now, it pressing up with 48, must ease

the

the beam of 48, and counterpoise so much of the superior VVater, and consequently the beam must support only 352 pound of it. But put the case (you say) the weight R, were 130 pound, 160 pound, or 180 pound, would the beam be less or more burdened with the superior Water? I answer, if R be 130 pound, then the beam supports only 132 pound of the superior Water; for if the inferior be only burdened with 130, the weight of R, and with two the weight of the inferior *plain*, then must it press up with 368, and by this means, must ease the beam of so much, it sustaining 132 pound only. According to this compting, when the Lead R weighs 160 pound, the beam supports only 238 pound of the superior Water. If it weigh 180 pound, it sustains 218. And if the weight R were taken away, the beam supports no more of the superior VVater than two pound.

To proceed a little further; imagine the two *Plains* to be drawn up 17 foot nearer the first surface I K, namely as high as Z W. This done, the union breaks up, and they presently fall asunder. The reason is, because the surface Z W is not able to support 352 pound, but only 300, which I prove thus. If 68 foot sustain 400, then 51 foot must sustain 300. I say 68, and not 34, because as was noted, the Pressure of the Air upon the surface I K, is equivalent to other 34 foot: and therefore though the deepness of this VVater, between I K and L M be but 34 foot really, yet it is 68 foot virtually, and in effect. Imagine secondly the surface I K to subside 17 foot, namely to Z W. In this case the union is broken also, and the lower *Plain* falls from the upper. The reason of this, is the same with the former; because by what proportion you diminish the hight of the superior VVater, by that

same

ſame proportion you diminiſh the upward Preſſure of the lower VVater. Therefore, if you ſubtract from the ſuperior VVater 17 foot, that weighs 100 pound, you ſubtract likewiſe 100 pound from the inferior VVater, and conſequently, you make it preſs up only with 300, but 300 is not able to counterpoiſe 352.

Let us ſuppoſe thirdly, the ſuperior *Plain*, and the ſuperior Water to be annihilated; then I ſay, the Preſſure and force of the under Water would thruſt up the inferior *Plain* and the weight R about eight foot higher then X Y and there ſuſpend them. The reaſon is, becauſe the ſurface X Y, being able to ſuſtain 400, and being burdened only with 352, muſt have the weight of 48. Now the upper *Plain* being taken away, and the upper Water alſo, and the empty ſpace of both remaining, the ſaid weight of 48 pound, muſt carry the under *Plain* as high as is ſaid. Let us ſuppoſe fourthly, the Preſſure of the Element of Air, that reſts upon I K, to be taken away, then muſt the two *Plain* bodies be diſunited, the inferior falling from the ſuperior. The reaſon is, becauſe in this caſe, the ſuperior Water would have but the weight of 200 pound, and conſequently the inferior, would preſs up only with as much: but 200 is not able to counterpoiſe 352.

From what is ſaid we ſee firſt, that in all Fluids there is an upward Preſſure, as well as a downward; and that the one is alwayes of equal force to the other: becauſe the inferior *Plain* is preſſed up with as great force, as the ſuperior *Plain* is preſſed down with. We ſee ſecondly, that in Fluids, there is a *Pondus* and a *Potentia*. The *Potentia* here is the inferior Water, and the *Pondus* is the ſuperior. Or, the 350 pound of Lead R, may be called the *Pondus*, which counterpoiſeth the *Potentia* of the ſurface

of VVater X Y. We ſee thirdly, that though the Preſſure of a Fluid, be not the ſame thing with the natural weight, yet it is equivalent to it: becauſe the 352 pound of Lead R, is ſuſtained by the Preſſure of the inferior VVater, which could not be, unleſs they were virtually the ſame. We ſee fourthly, that there may be as much Preſſure in one foot of Water, as there is weight in 100, or in 1000 foot, or in 1000 fathom, For put the caſe, theſe two plain bodies were ſuſpended, 100 fathom below the ſurface of the ſea, and within a foot or two of the ground, as much weight would be required to pull them aſunder, as is the weight of a Pillar of Water 100 fathom high, and 4 inches thick every way, which will be more then 3000 pound weight, beſides the weight of the Air above, that will weigh 200 pound. This could not be, unleſs there were as much Preſſure in the loweſt foot of this Water, that's 100 fathom deep, as there is weight in the whole Pillar above. We ſee fifthly, the more the *potentia* of a ſurface is burdened, the more ſenſible is the *pondus*: becauſe the heavier you make the Lead R, that burdens the inferior Water, the more weight of the ſuperior Water reſts upon the Beam. We ſee ſixthly, the more *unequally* a body is preſſed, the more the Preſſure is *ſenſible*. For underſtanding this, conſider that the under-face of the ſuperior *Plain*, is more and leſs preſſed, according to the more and leſs weight the Lead R is of: for put the caſe, the inferior *Plain* were taken away, the face of the ſuperior *Plain*, would be equally preſt with the back of it. But when the inferior *Plain* is united to it, the Preſſure of the Water is kept off; by which means the back is preſt more than the face. Now, as the inferior *Plain* becomes heavier and heavier, by making the weight R more and more

weighty,

weighty, the less and less is the face of the superior *Plain* prest up. Hence it is, that as this inequality of Pressure becomes greater and greater; so the weight of the superior Water, affects the Beam more and more. Or, if the superior *Plain* were a sensible body, as *Animals* are, it would find the back of it more and more burdened, according as the weight R, becomes heavier and heavier. We see seventhly, that Water weighs in Water: because all the weight the Beam supports, is the burden of the superior VVater, and not the burden of the inferior *Plain*, or of the weight R· It supports the weight also of the superior *Plain*, but this is not considerable. This is only to be understood, when the Pressure is unequal; for if the upper *Plain* were as much prest up, as it's prest down, the weight of the superior VVater would not be found by the *Beam*. We see eighthly, that the higher a surface be, it is the weaker; and the lower it be, it is the stronger: because when the two plain bodies are pulled up, 17 foot, they fall asunder. We see ninthly, the vanity of the common opinion, that maintains two plain *bodies* to cleave closs together for fear of *vacuity*; and that neither *Humane* nor *Angelick* strength is able to break this union, without the rupture and fracture of them both.

It may be enquired, upon supposition, that the inferior *plain* had four holes cut thorow the middle, square-wise, as A B C D in the 18 Figure, what *Phenomena* would follow? Before I answer, consider that this Figure represents the inner face of the Brass-plate C D N O, of the 17 Figure, which as was supposed, is four inches from side to side, and consequently contains 16 square inches. Now, imagine the under *plain* C D N O, while it is united to the uppermost, to have four square inches cutted out of it,

as A B C D. Theſe things being rightly conceived, and underſtood, I ſay, when the ſaid holes are cutted thorow, the beam T V, that now ſuſtains 350 pound, ſhall by this means, only ſuſtain 250 pound. To make this evident, conſider that the under *plain* (as was ſaid) contains 16 ſquare inches. Next, that the top of the inferior Water upon which the *plain* reſts, contains as many, and that every inch of the Water weighs 25 pound, ſeing the whole, as was ſuppoſed before, weighs 400 pound. Now, I ſay, the beam muſt ſupport only 250 pound of the Water I K L M; becauſe, theſe holes being made, the top of the inferior Water comes through them, and preſſeth up the face of the ſuperior *plain* with 100 pound, and ſo eaſeth the beam of ſo much. I affirm next, that though the inferior Water N O P Q be in it ſelf 400 pound, and conſequently able to ſupport the inferior *plain*, with the weight R, albeit they weighed ſo much, yet the ſaid holes being cut out, it is not able to ſupport more burden than 300. The reaſon is, becauſe of 16 parts that did actually bear up before, there are only 12 now that ſuſtains. And every one of theſe twelve, being but able to ſupport 25 pound, it neceſſarily follows, that the greateſt weight they are able to ſuſtain, is 300 pound. I affirm thirdly, that if a fifth hole were cut through, the under *plain* would fall from the upper; becauſe in this caſe, the inferior Water is not able to ſupport 350 pound as before, ſeing of 16 parts, there are five wanting, and eleven remaining, cannot ſupport more weight than 275 pound. Moe queſtions of this kind might be propoſed; as firſt, what would come to paſs, if the the upper *plain* had as many holes cut through it, anſwering to the four of the nether? Secondly, what would follow, if the nether *plain* were intire, and four bored through

the

the upper? But I shall supersede, and leave these to be gathered by the judicious Reader.

From this Experiment we see first, that the broader and larger a surface of a Fluid be, it's the more able to sustain a burden, and the narrower it be, 'tis the less able. Secondly, that each part of a surface, is able to sustain so much weight, and no more, and no less.

Before I put a close to this Experiment, it will be needful to answer an objection, proposed by *Doctor More* in his *Antidote against Atheism*, against the Pressure of the Air, which in effect militats, by parity of reason, against the Pressure of the VVater likewise. He argues thus. If the Air were indowed with so much Pressure, as is commonly affirmed, then it ought to compress, squeez, or strain together, any soft body that it environs, as, *v.g. Butter*. Put the case then, there were a piece of *Butter*, four inches broad every way, and one inch thick, containing 16 square inches, upon every side; as may be represented by the Figure 19. In this case, there is a far greater Pressure, upon the two faces, than upon the four edges; and therefore, it ought to be compreſt, and strained together, to the thinness of a sheet of Paper. For answer, let us suppose the piece of *Butter*, to be 30 or 40 foot below the surface of a Water, where it ought to suffer far more Pressure, than above in the Air. Next, that it lies *Horizontal*, with one face upward, and the other downward. Thirdly, that the upper face supports a Pillar of Water 200 pound weight, and consequently, that the under face is preſt up with as much. And lastly, that every edge is burdened with 50. It may be represented, with the help of the fancy, in the 19 Figure, where A B is a piece of *Butter* four inches square, and one inch thick. Only take

notice,

notice, that nothing here is represented to the sight, save one of the four edges, namely A B; the other three, and the two faces being left to the fancy: Yet, the upper face may be represented by F H K M, and the under by N O P Q. These things being rightly understood, it is wondered, why the two great and heavy Pillars of Water, the one E G I L F H K M, that presseth downward, and the other N O P Q R S T V, that presseth upward, do not strain together the sides of the *Butter*; seing the Pressure of the Water B C, and the Pressure of the Water D A, are far inferior to them for strength, even by as much difference, as four exceeds one. Though this objection seem somewhat, yet it is really nothing, which I make evident after this manner. First, I grant that the upper face F H K M is burdened, with 200 pound, and the nether face N O P Q with as much. Secondly, that the edge B, is only burdened, with 50 pound, as is the edge A. The other two edges, sustains each one, as much. Secondly, though this be, yet I affirm the two sides to be no more burdened, than the edges: that's to say, the Pressure upon the sides, is equal to the Pressure upon the edges, which I prove thus. The Pressure upon the part M, is equal to the Pressure upon the part K, but the Pressure upon the edge B, is equal to the Pressure upon the part M: therefore the Pressure upon B, is equal to the Pressure upon K. The major Proposition is evident, because the Pillar of Water L M, is of the same weight, with the Pillar of Water I K. The Minor is also evident, because, the Pillar B C, is of the same weight, with the Pillar L M. Now, if the Pressure upon the edge B, be equal to the Pressure upon M and K, it must be likewise equal to the Pressure upon H and F. If this be, then the edge

Fig. 12 Pag. 81

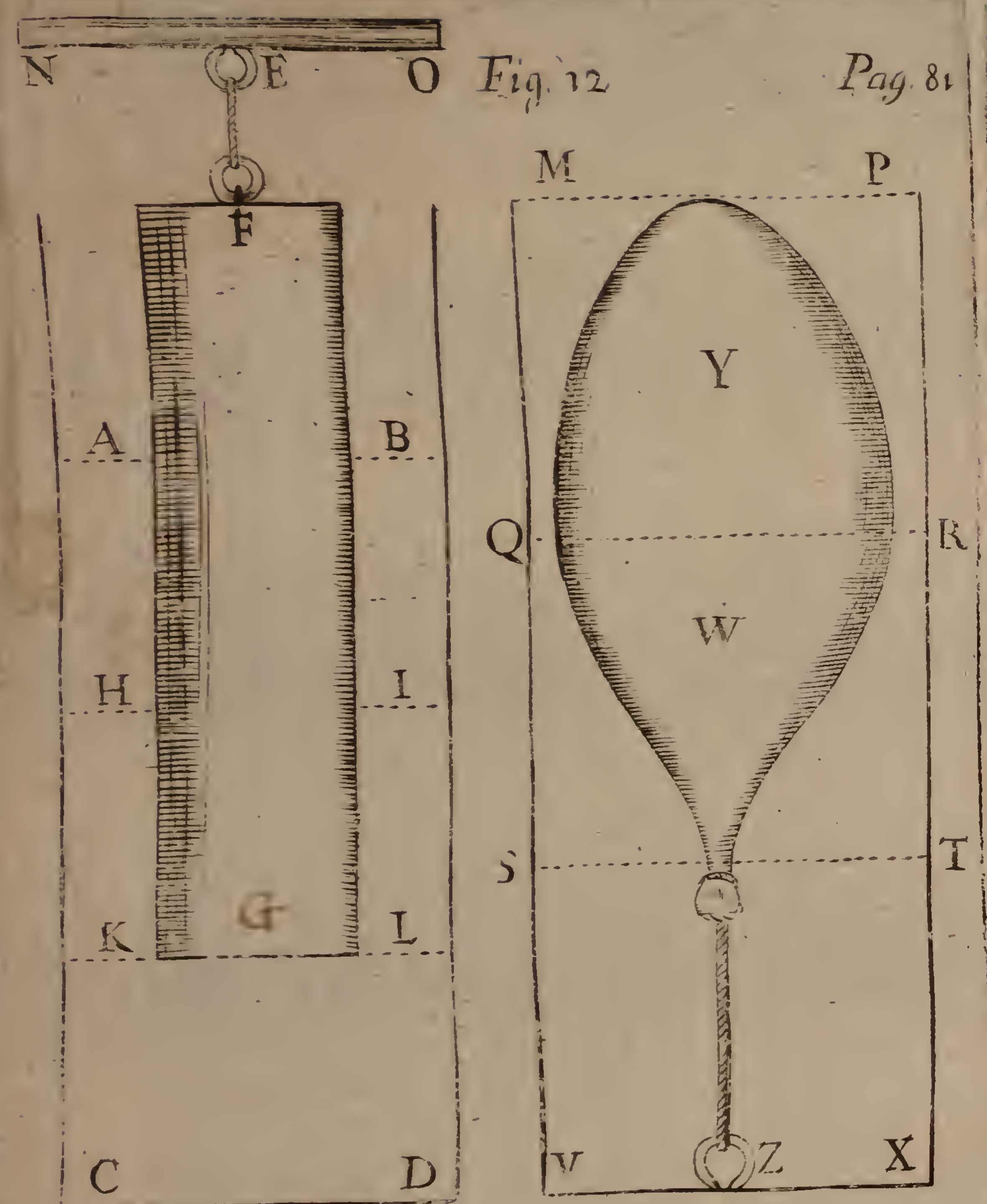


Fig. 15 Pag.

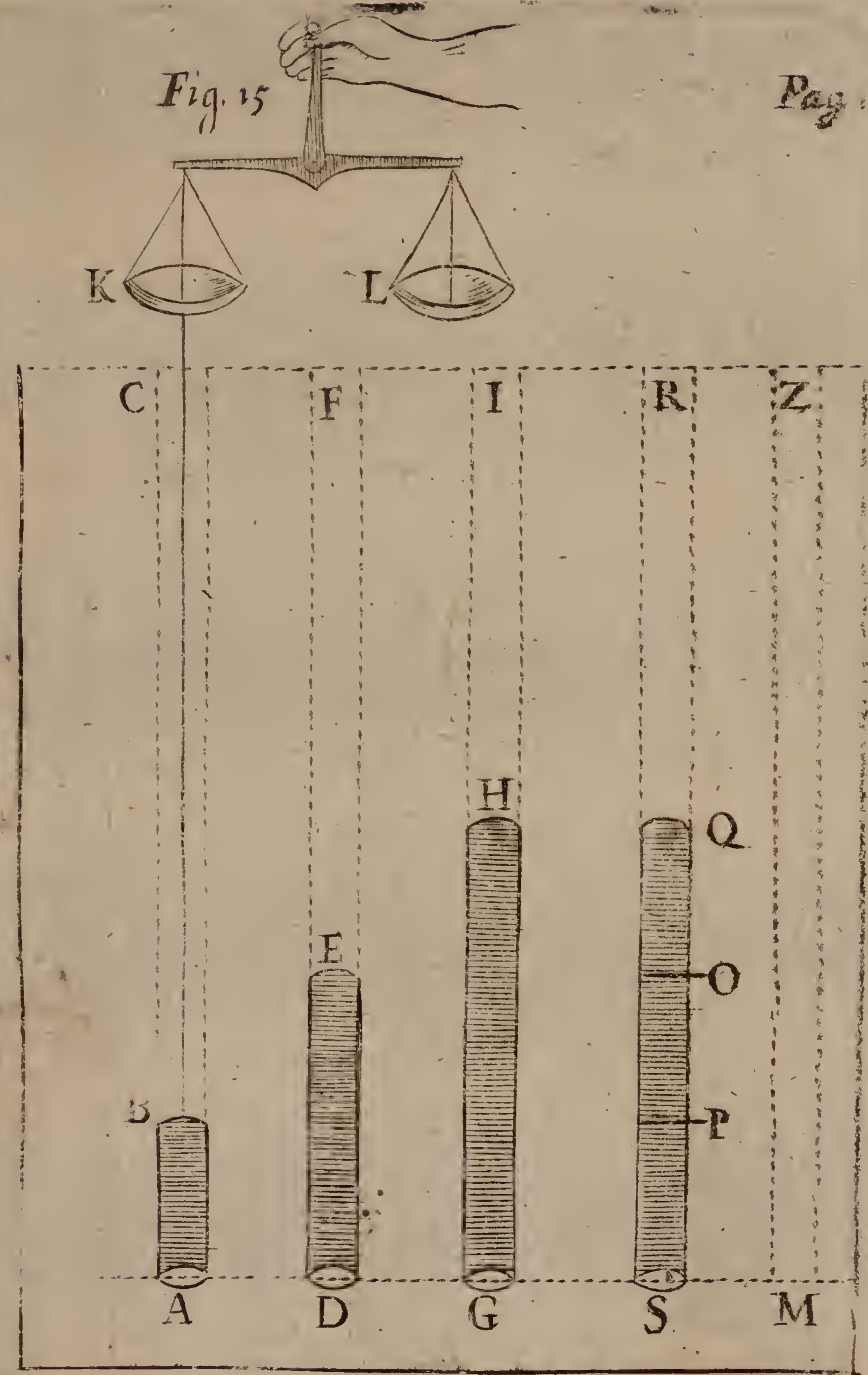


Fig. 16 Pag. 109

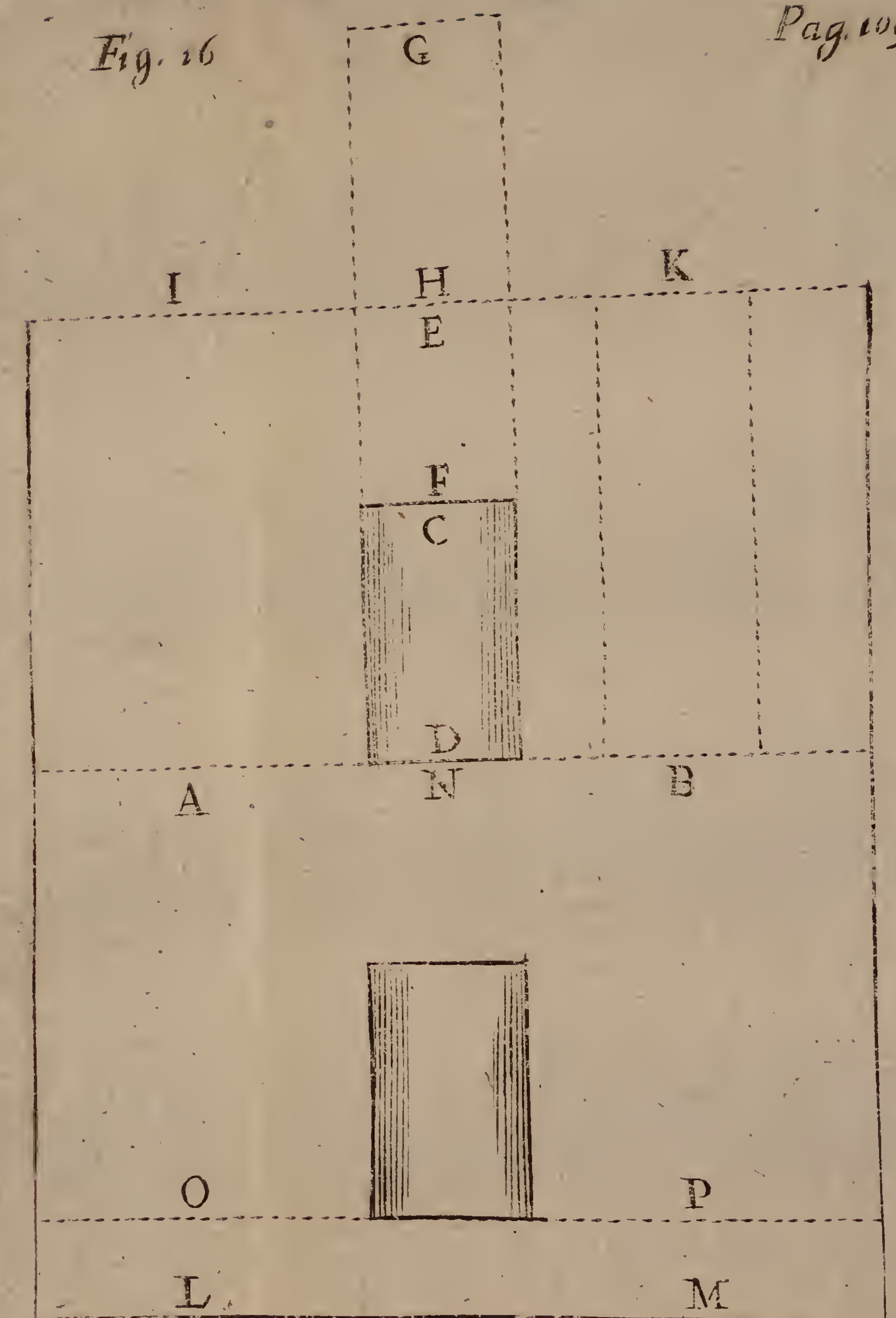
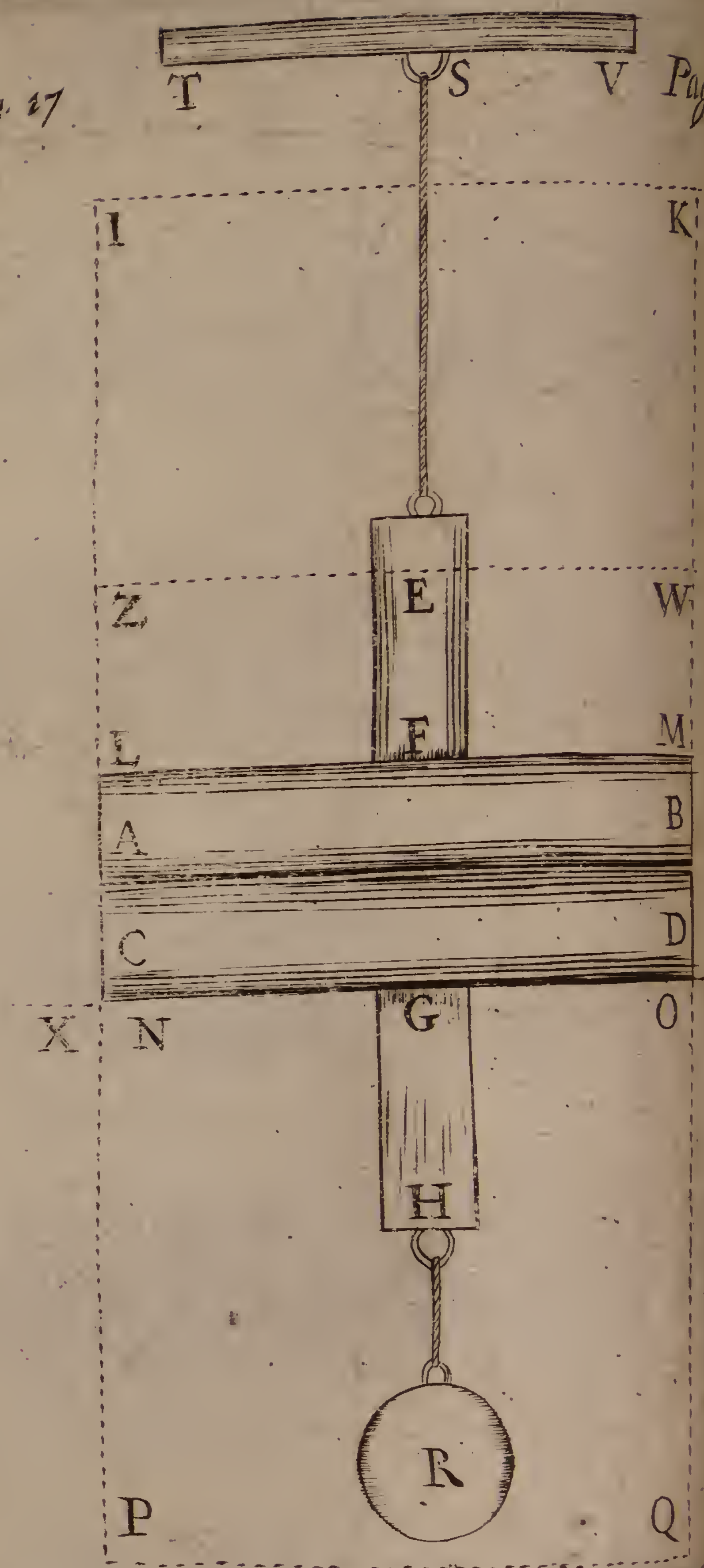


Plate 4

Fig. 17 Pag. 113



edge of the *Butter* B, must be no more prest, than the side F H K M: therefore the Water B C, can no more yeeld to the VVater E F G H I K L M, and suffer the *Butter* to be squeezed out at B, than the VVater L M, can yeeld to the VVater E F G H I K, and suffer the *Butter* to be squeezed out at M. If any man shall insist and say, that the upper face bears the weight of four Pillars, which weighs 400 pound; but the edge B is only burdened with 50: therefore 50 ought to yeeld to 400. I answer, according to the 29 Theorem, namely, that a *thicker* Pillar of a Fluid is not able to press, or move a *slenderer*, unless there be an unequal Pressure, therefore the thick Pillar, that presseth the face, cannot move the slender Pillar, that presseth the edge: but there is here no unequal Pressure, seing the Water X Y Z V, is of the same hight with the four Pillars that rests upon the face of the *Butter*. I grant, if the said Water were not so high, as the other is, by the one half; then surely the *Butter* would be squeezed out at B; because the shorter a Pillar be, the less Pressure is in the surface under it; therefore, there must be less Pressure, according to that supposition in the Water B C, then now is. Or put the case, the Pillar I K were shorter then G H, or L M, the same effect would follow, namely, a squeezing out of the *Butter* from K. Or, let us suppose the Pillar I K, to be higher than G H or L M. In such a case, the weight of the said Pillar would press through the *Butter*.

From what is said, we shall only inferr this conclusion, that equality of hight between Pillars of a Fluid makes equal Pressure, and inequality of hight makes unequal Pressure. Therefore 'tis no matter, whether they be gross or small, thick or slender, provided they be all of the same Altitude.

EXPE-

EXPERIMENT XIV.

Figure 20.

THis Schematism represents a Vessel full of Water 8 foot deep. E F is a Glass-Pipe, open at both ends, about 9 foot high, and one inch in Diameter. A B C D is a Vessel of Glass, or of any other metal, thorow whose orifice above, the said Pipe comes down. B H I is a Pipe going out from the said Vessel, crooked with a right angle at H, that the orifice I may look upwards. That some *Hydrostatical* conclusions may be inferred from this Experiment, fill the lower Vessel A B C D with Quick-silver almost; then pour in as much Water above it, as will fill the space A B H, leaving from H to I full of Air. Next, thrust down the orifice of the Pipe E, below the said Water and Mercury, till it rest upon the bottom C D. Lastly, stop well with cement the passage of the lower Vessel, through which the Pipe came down, that neither Air nor Water may go out, or come in. These things being done, let down this *Engine* to the bottom of the large Vessel, which, as was noted, is full of VVater from M N to K L, 8 foot, and you will find the Mercury to rise in the Pipe from A B to G, 6 inches, and more. The reason is, because there is a Pillar of VVater K I, that enters the orifice I, and presseth down the Air, from I to P, 3 inches, which before was 6. This Air being so burdened; instantly presseth forward the VVater H B A: and this pressing the surface of the stagnant Mercury A B, causes the liquor run up the Pipe from A B to G, 6 inches: The reason, why it riseth 6 inches, is this: between the surface of the stagnant Mercury A B, and the top of the water

Water L O K, are 84 inches. Now Water being 14 times *naturally* lighter then Mercury, there muſt be 14 inches of Water, required for ſuſtaining one inch of Mercury, and conſequently 84, for ſupporting 6. For a ſecond trial, lift up the whole *Engine* to the top of the Water, and you will find the 6 inches of Mercury B G ſink down, and become no higher within the Pipe; than the ſurface of the ſtagnant Mercury A B without. The reaſon is, becauſe by coming up above the Water, the Preſſure of the Water K I, is taken away from the orifice I, by which means the compreſt Air H P, extending it ſelf to I, liberats the Water A B H of the Preſſure it had, and this freeth the Mercury of its Preſſure, and ſo the 6 inches falls down. For a third trial, ſtop cloſely the orifice I, and let all down as before. In this caſe, you will find no aſcent of Mercury from B to G: becauſe the Water K I cannot have acceſs to thruſt down the Air from I to P, as formerly.

For a fourth, open the ſaid orifice I, while the *Engine* is below the Water, and you will find the Mercury riſe from B to G: becauſe the Pillar of Water K I, hath now acceſs to preſs. For a fifth trial, ſtop the orifice I, and bring up all to the top, and you will find the ſix inches of Mercury B G ſuſpended, as if the *Engine* were under the Water. The reaſon is, becauſe the ſtopping of the orifice, keeps the incloſed Air P H, under the ſame degree of Preſſure it obtained from the Water K I. For a ſixth proof, open the ſame orifice I, while the *Engine* is above the Water, and you will find the ſix inches of Mercury fall down, becauſe the impriſoned Air H P, obtains now its liberty; and expanding it ſelf from H to I, eaſes the Water B H of the burden it was under. For a ſeventh, pour in 14

inches of Water at the orifice F, till it rest upon the top of the Mercury at G, and you will find one inch fall down. Pour in as much, and two inches falls down. In a word, pour in as much Water, as will fill the Pipe to O, and you will find the whole six inches fall down. The reason is, because the Water K I, is not able to sustain, both the six inches of Mercury and the Water, that's poured in; any one of them being able and sufficient to counterpoise it. For an eighth trial, empty the Pipe of the said Water, and after the Mercury is ascended from A B to G, as formerly, suck out the whole Air between G and F, and you will find the Mercury to rise from G to R 29 inches. The reason of this is evident from the Pillar of Air S K, that rests upon the top of the Pillar of Water K I: for by sucking out the said Air, you take away the *pondus* or weight, that counterpoised the weight of the Pillar S K, therefore it finding its counterpoise removed, presently causeth the Water K I, to enter farder within the crooked Pipe, till it hath prest up the liquor to R. For a ninth trial, take the six inches of Mercury B G, and put them into the scale of a ballance; then take as much Water, as will fill the Tub between A B and O, and put it into the other scale, and you will find a most exact counterballance between them. The reason is, because if the Water K H, or a Pillar of that hight, be able to raise and counterpoise the Mercury B G; then must as much Water, as fills the Pipe betwen B and O, be the just weight of it. The reason of this consequence is, because these two Waters are of the same weight: therefore, if the one be the just weight of it, the other must be so too. If it be said, that the Water, that fills the Pipe between B and O, is far

thicker,

thicker, then the Water KH; therefore they cannot be both of one weight. I answer, equality of *altitude*, in this *Ballance of Nature*, is equality of *weight*: therefore, seing the one Water, is as high as the other, they must be both of one weight. If it be said, that a Pillar of Water between K and H, cannot counterpoise the six inches of Mercury BG, both being put into a ballance: and the reason is, because the one is thicker than the other. I answer, this only proves that two Pillars differing in weight in the *Libra* or *Artificial Ballance*, may be of one weight in the *Natural Ballance*: because in the *Artificial Ballance*, bodies counterpoise one another, according to all their dimensions, but in the *Natural Ballance*, such as this *Engine* is, Fluids counterpoise one another, according to their *altitude* only.

From the first trial, we conclude first, that Water even in its own place *gravitats* and *weighs*, because this Water by its Pressure, *de facto* thrusts up 6 inches of Mercury. We see in the next place, that the Pressure of a Fluid, is as easily communicated *Horizontally*, as *Perpendicularly*; because the Pressure runs alongst from H to B. We see thirdly, that Fluids, may have as much Pressure begotten in them, even while they are environed about closely with solid bodies, whereby the superior Pressure, immediatly and directly by perpendicular lines is keeped off, as if they were immediatly under the Pressure: because the Mercury ABCD, is as much burdened with the Pressure, that comes from H, as if the upper part of the Vessel AB, were open to let in the superior Pressure, by perpendicular lines. The Air then under the roof of a house, is under as great a Bensil and Pressure, as the Air without, that's directly under the Pressure of the Atmosphere.

VVe see fourthly, that the Pressure of a Fluid, may be as easily communicated thorow the parts of *Heterogeneous* Fluids, as thorow the parts of *Homogeneous*; because the Pressure of the VVater K I, is as easily communicated thorow the Air P H, thorow the Water H B, and thorow the stagnant Mercury B D to the orifice E, as if nothing interveened but VVater. VVe see fifthly, that Mercury can suffer a Pressure, as well as VVater or Air; because the six inches cannot rise from B to G, unless the stagnant Mercury A B C D were compresed, even in all the parts of it.

From the second trial, we see, that there cannot be a *Pondus* in a Fluid, unless there be a *Potentia*, to counterpoise it: for when you take away the Water R I, by lifting up the Engine to the top of the Water, the Mercury B G presently falls down. From the third trial, we conclude, that the Pressure of a Fluid, cannot be communicated thorow solid Bodies: for when the *Engine* is drowned below the Water, with the orifice I, stopped, no ascent of Mercury follows. We conclude from the fourth trial, that it is impossible for two Fluids to counterpoise one another, unless they be *in Equilibrio*, because the Water K I cannot sustain the Mercury B G, unless it be of the same weight. From the fifth, we conclude, that a Fluid may be keeped under the same degree of compression, after the superior weight that begat it, is taken away: for after the *Engine* is brought above the Water, with the orifice I stopped, the Mercury B G is still suspended, even by vertue of the Pressure, that's in the stagnant Mercury. This tells us, that a sphere of glass full of Air, may retain its *Bensil*, even though the whole Element of Air, that begat it, were destroyed. From the

sixth

sixth we gather, that a Fluid cannot abide under Pressure, when the burden is taken away that begat it, or that keeped it under Pressure: for by opening the orifice I, the Air P H extends it self: and so are the VVater, and Mercury within the Vessel freed of their Pressure likewise. We gather from the seventh trial, that in the *Ballance* of *Nature*, one Scale cannot be more burdened then another; or that two *Fluids* cannot counterpoise one another, unless they be *in equilibrio*: for when you pour in 14 inches of Water, upon the top of the Mercury at G, they thrust down one inch, that there may be a just *equipondium*, between them, and the opposite weight K I. We gather from the eighth trial, which was observed before; first, that there cannot be a *Potentia* in a Fluid, unless there be a *Pondus* to counterpoise it: for when you suck out the Air G O, which was the *Pondus*, that counterpoised the Air S K, this presently in stead of it, raiseth 29 inches of Mercury from G to R. We see secondly, that one pillar of Air can counterpoise another, Fluids of diverse kinds interveening: because the Air S K, counterpoises the Air within the Pipe G O, the VVater K P first interveening; the Air P H next interveening, and the stagnant, and suspended Mercury interveening also. We see thirdly from this eighth trial, that the Pressure of the *Atmosphere*, may be communicated thorow diverse kinds of Fluids, without the least diminution of its weight: because the weight of the Pillar of Air S K, is communicated, and sent down thorow the Water K I, thorow the Air P H, thorow the VVater H B, thorow the stagnant Mercury B D, and up thorow the suspended Mercury B G, till it suspend the 29 inches between G and R, which is the just counterballance of it. We see moreover, that Fluids counter-

poise

poise one another, according to *altitude* only, and not according to *thickness* and *breadth*; by comparing the Water K I, that's but half an inch thick, to the Mercury B G, that's a whole inch thick. We see from the last trial, that when a Fluid is necessitated, to counterpoise a Fluid of another kind, in stead of a Fluid of its own kind, it sustains no more of it, than what is the just weight of the Fluid of its own kind, because the VVater K I, being under a necessity to counterpoise the Mercury B G, in stead of so much VVater as would fill the Tub, it sustains no more of it, than the just weight of so much VVater, as is said. We see secondly, that when two Fluids of divers kinds, do counterpoise one another, that which is heaviest *in specie*, hath alwayes the shortest Cylinder. Next, that the difference between their altitudes, is most exactly according to the difference between their *natural* weights, therefore B G is 14 times lower than B O; because Mercury is 14 times heavier than VVater. We see moreover, that though two Cylinders of a Fluid, can counterpoise one another in the *Natural Ballance*, such as this *Engine* is, yet they will not do it in the *Artificial Ballance*: because though B G counterpoise K I in this Ballance, yet in a pair of Scales, the Mercury will be as heavy again as the VVater. We see lastly, that notwithstanding of this, yet such a thing may be; for if the orifice I, were made as wide as the orifice F, that the Cylinder KI might be equal to the Mercury B G in thickness, then surely the one would counterpoise the other in the *Libra* or *Artificial Ballance*.

EXPE-

EXPERIMENT XV.
Figure 21.

THis Schematism represents a Water 72 foot deep, as C D A B, together with a crooked Pipe of glass I N H, the one half whereof is I P, 56 inches high, and one inch wide, the other half is P N R H, of a far narrower diameter, with an orifice H. There is also an orifice at L, with a neck, about which is knit a small chord M L, for letting down this *Engine* to the bottom of the VVater A B. For trials cause, fill the wide glass with Mercury from P to K, and you will find it rise in the narrow Pipe, as high as the orifice H. This being done, close hermetically, or with good cement the orifice L; then by help of this chord, let all go down from the surface C D, till it be exactly 17 foot from the top, and you will find the Mercury thrust down in the narrow Pipe, from H to R, 14 inches and an half. Let it down next, as much, and the Mercury will be yet further thrust down, namely from R to N, the part H R N being full of Water. For understanding the reason of this, consider that between N and E, are 34 foot: for so high is the slender Pillar of Water, that comes from the top, and entring the orifice H, comes down thorow the Pipe to N. Consider next, that between the said Pillar of Water, and the Mercury N P K, there is a counterpoise: but this counterpoise cannot be, unless the Pillar of Water be 34 foot high; seing between N and K are 29 inches of Mercury; for each inch thereof requires 14 of Water. Upon this account it is, that when the glass is 17 foot drowned, 14 inches and an half are thrust down from H to R. If it be objected, that the *Pressure* and *Bensil* of the inclosed Air

IK;

I K ; is equivalent to the weight of other 29 inches ; and therefore the Pillar of Water E H R N , must be 68 foot high, before a counterpoise can happen. I answer, 'tis true that's said, but you do not consider, that there is a Pillar of Air F E, resting upon the top of the Pillar of Water, that makes a compensation exactly. To speak then truely and really, the 29 inches of Mercury N P K, have the weight of 58 inches ; and the 34 foot of Water E H R N , have the weight of 68 foot.

For a third trial, let down the glass 6 foot further, and you will find the Water pierce up thorow the thick Cylinder of Mercury P K , and rest upon the top K. The only difficulty is to determine, how much will spring up before the motion of it cease? 'Tis evident, that the Water will ascend, because coming to the *Base* of a thick and gross Cylinder, that it cannot intirely lift, it must pierce thorow it, seing the force of such a Pillar of Water, is now much stronger, than the Mercury : for in effect, the glass being drowned 6 foot further, the Pillar that comes down thorow the slender Pipe, hath the just weight of 34 inches of Mercury : but 29 cannot resist 34 : therefore the Water not being able to lift it, by reason of the disproportion that's between the thickness of the one, and the slenderness of the other, it must pierce up thorow it. For clearing this difficulty, consider, that this glass cannot go down from one imaginary surface to another, *v. g.* from 34 foot, where it was, till it come to 40, where it now stands, but there must be an alteration in the *equipondium*, seing by going down, the Pillar of Water E H R N grows higher, and consequently heavier ; and therefore, some VVater must pierce up thorow the Mercury , for making a counterpoise ; for 'tis impossible for two Fluids to counterpoise one another, unless

unleſs they be in *equilibrio.* Conſider ſecondly, that after the Water is come to the top of the Mercury at K, it will find difficulty to find a room for it ſelf, ſeing the ſpace between S and I is full of Air. Notwithſtanding of this, it muſt aſcend. I ſay then, after the glaſs is gone down from 34, to 40 foot, there will be about four inches of VVater above K, which have reduced the 29 inches of Air K I, to 25, S I.

If it be asked, between what two things is the *equipondium* now? I anſwer, the firſt was at R, between E H R, and R N P K. The ſecond was at R, between N R H E, and N P K. The third is now at S, between the 25 inches of incloſed Air I S, as one Antagoniſt, and the four inches of Water S K, with the 29 inches of Mercury K P, and the Water P N R H E, as the other. To make a fourth *equipondium,* ſink the Glaſs other ſix foot, till it be 46 foot from the top C D, then muſt ſome more VVater ſpring up thorow the Mercury ; this of neceſſity muſt be, ſeing the Cylinder of VVater N R H E, is ſix foot higher, and ſo far heavier, than it was: if this be, then muſt the 25 inches of Air I S, be reduced to leſs quantity; ſeing 'tis impoſſible, for one Fluid to become heavier, unleſs its oppoſite and *antagoniſt* become heavier too, for an *equipondiums* ſake. Note, that the Air I S, will not loſe other four inches, with this ſix foot of VVater, as it did with the former. The reaſon is, becauſe, if for every ſix foot the Glaſs goeth down, the Air were compreſt four inches, it were eaſie at laſt to reduce it to nothing: for if ſix reduce it to four, and 12 to eight, 38 ought to reduce it to no inches, which is impoſſible. Therefore I judge it muſt ſuffer compreſſion, by a certain proportion, as we ſee upon a Scale, the diviſions of *Artificial* or *Natural*

Sines grow leſs and leſs, there being more ſpace between 1 and 2, than between 2 and 3; more between 2 and 3, than between 3 and 4, and ſo upward till you come to *90*. Therefore the ſecond ſix foot, muſt reduce the 25 inches, not to 21, but to 23 *circiter*, and ſo forth. By the which means, though the Glaſs ſhould go down *in infinitum*, yet the Air ſhall never be reduced to nothing, and there ſhall ſtill ſome ſmall quantity of VVater come up. Or in ſuch a caſe, the Air may be ſo compreſt, that it can be no more, all the *diſſeminate vacuities* being expelled. But ſuppoſe this to be at 1000 fathom, then at 1500, where the Preſſure is ſtronger, there can be no *æquipondium*, which is abſurd, for where the *pondus* becomes ſtronger, the *potentia* ought to grow ſtronger likewiſe. I anſwer, the motion of condenſation ceaſeth indeed; but there ſtill remains a *potentia*, or rather in ſuch a caſe, a perfect *reſiſtentia*, whereby the Air is able to reſiſt the greateſt weight imaginable, before it can be reduced to nothing; or ſuffer a penetration of parts, that's to ſay, two parts to be in one ſpace.

From the explication of theſe Phenomena we conclude firſt, that in Water there is a conſiderable Preſſure, ſeing in letting down the Glaſs 17 foot, the Mercury is preſt down from H to R, and from R to N, in going down other 17 foot. Secondly, that *29* inches of Mercury are as heavy as 34 foot of VVater: becauſe the Mercury K P N makes a juſt *equipondium* with the VVater E H R N. Thirdly, that Fluids not only of the ſame kind, but of different kinds, do counterpoiſe one another according to *altitude*, and not according to *thickneſs*; becauſe though the Mercury K P N be far thicker, than the VVater E H, yet they counterballance one another, becauſe a proportion is kept according to their *altitudes*. Fourthly, that a

Fluid

Fluid *naturally* lighter, may move a Fluid *naturally* heavier, and thrust it out of its own place, because the Water coming in at H, thrusts down the Mercury to R, and from R to N, and so forth. Fifthly, that of two Fluids unequal in strength, debating together, the weaker of necessity must yeeld to the stronger, though the weaker be far heavier naturally than the stronger, as is evident in the Mercury, that yeelds to the Water. Sixthly, that it is impossible for two Fluids, so long as they are unequal in strength, to cease from motion, till they come to an *equipondium*; because the Water alwayes springs up thorow the Mercury, till an equal Ballance happen. Seventhly, that one Fluid of this kind, can counterpoise another Fluid of the same kind, though there be divers Fluids interveening: because the Air F E, counterpoiseth the Air I K, or I S, notwithstanding of Water and Mercury interveening. Eighthly, that there may be as much Pressure in one inch of a Fluid, as in a million; because the 29 inches of Air I S, have as much *Bensil* in them, as is in the whole Pillar of Air E F, that goeth up from the top of the VVater, to the top of the *Atmosphere*. Ninthly, that when one Fluid is under Pressure, the next must be under the same degree of Pressure, though they be not of the same kind, but of different sorts; because the Air I S, the Water S K, and Mercury K P, are surely under the same degree of Pressure; otherwise the motion could not end. Tenthly, that when two Fluids of divers kinds do press one another, that which is *naturally* lighter, ascends alwayes to the higher place, and the heavier to the lowest: because the Air I S, is above the Water S K, and the Water S K is above the Mercury. Note, that this is not universal, but only happens when the lighter Cylinder, is slenderer than the other, for if the

Mercury K P; were no thicker than the Water P N R H, this would raiſe it intirely. Eleventhly, that the compreſſion of Air to leſs ſpace, is not according to *Arithmetical progreſsion*, 1, 2, 3, 4, 5, but according to ſome other proportion, which may be called *Uniform-difform*. Note here, that though this be true of the Air, while it is compreſt from a more quantity to a leſs, as here, or in a *Wind-Gun*; yet it is not true of the Preſſure of the Element of Air, which is more and more from the top of the *Atmoſphere* to the *Earth*, according to *Arithmetical Progreſsion*, as in Water. We ſee laſtly, that the heavieſt of Fluids, ſuch as Mercury, preſs upward, as well as downward; becauſe the top of the Mercury K, thruſts up the Water K S, as well as it thruſts down the Water P N R H. It may be enquired here, how far this Glaſs would go down, before the 29 inches of Air I K were reduced to one inch? I anſwer, its hard to determine; but it ſeems it ought to go down more than 300 fathom. In this caſe, there would be 28 inches of Water above K. Let us ſuppoſe the orifice H to be ſtopped at that deepneſs, and the Glaſs brought above the Water; then, when the ſaid orifice is opened in the Air, you will find the whole VVater P N R H thruſt out: and not only this, but the whole Mercury P K, ſpring out at the orifice H likewiſe, except a little that remains between N and H: the reaſon is, becauſe the 29 inches of Air, being reduced to one, would be under a very great *Benſil*; therefore the weight being taken away that begat it, of its own accord, it would expand it ſelf to its old dimenſions; which it could not do, unleſs both the 28 inches of VVater, that's ſuppoſed to be above K, and the Mercury K P were thruſt out of their places.

EXPE-

EXPERIMENT XVI.
Figure 22.

THis Schematism represents a vessel full of VVater 84 inches deep, namely from L N the first surface, to M R the bottom. From M to R in breadth are 20 inches. There are here also two Glass-Pipes open at both ends; the one, two inches wide, the other half an inch wide. Both of them are 85 inches long. X Y O is a surface of stagnant Mercury, among which the two ends of the Pipes are drowned. E C is a Pillar of Mercury six inches in height, and so is GD, both of them raised to that altitude, by the Pressure of the Water upon the surface X Y O. The Pillar E C A is supported by, and rests upon, the imaginary Pillar A P. And so is the Pillar G D B, supported by the Pillar B Q. There are three things that occurres here from this operation of nature to be enquired after. First, why ought the Mercury to rise in the two Tubs, after the Vessel is filled with Water? Secondly, why rather six inches, then seven or eight? Thirdly, what's the reason, why it rises as high in the wide Tub, as in the narrow? I answer, the Mercury rises from C to E, and from D to G, by the Pressure of the Water, that rests upon the surface X Y O. Before that the Water is poured into the Vessel, there is here a most equal and uniform Pressure upon the surface X Y O, both without and within the Tub, namely from the Air that rests upon it. But no sooner is the Water poured in, but as soon the Pressure becomes unequal; the parts of the surface without the Tub, being more burdened, then the parts C and D within. Therefore, the part that's

less

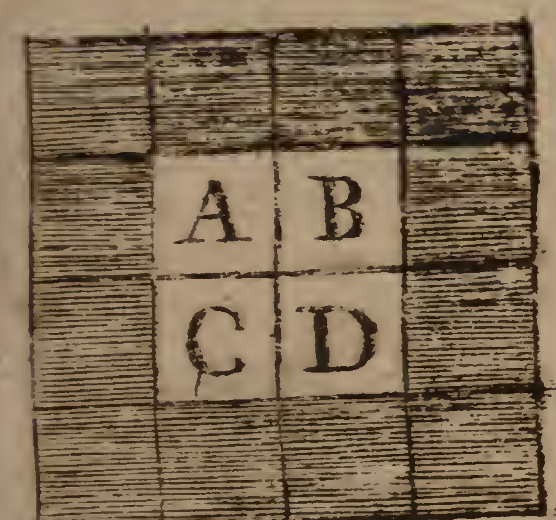
lefs preft, muft rife and climb up, till the Preffure become equal: for it's impoffible that a Fluid can ceafe from motion, fo long as there is inequality of weight between the *pondus* and the *potentia*. If any doubt, let him pierce the fide of the Veffel, and when the whole Water is run out, he will find E C and G D to have fallen down, which clearly proves the climbing up of the Mercury, to depend upon the in-pouring of the Water. For underftanding the reafon of the fecond, remember that Mercury (as we have often noted) is counted 14 times heavier then Water; therefore E C muft be fix inches, feing X Y O is preft with the altitude of 84 inches of Water. It would be judged no marvel, to fee the Mercury rife from C to E, and from D to G, provided the face of the ftagnant Mercury were as high as Z F. No more ftrange it is, to fee the two Mercuries rife, with the Preffure of the Water; for in effect and really, the faid Water is the juft weight of as much Mercury as would fill between X O and Z F. For underftanding the third, remember (as was noted before) that Fluid Bodies counterpoife one another, only according to *altitude*: therefore 'tis no matter, whether the Tubs be wide or narrow. If it be enquired, how can one and the fame Water, counterpoife two Fluids of different weights? To fay, that Fluids counterpoife one another according to *altitude*, doth not clear the difficulty; for it ftill remains to be asked, why they counterpoife one another after this manner? Therefore it feems, that if the Water raife the Mercury from C to E in the wide Pipe, it muft raife it in the narrow one from D to K. For anfwer, confider firft, that as there are here two Pillars of Mercury C E, and D G within the two Tubs, fo there are here alfo two Pillars of Mercury A P and B Q, under the

the two orifices, upon which the ſaid two Pillars ſtand, and reſt. Conſider ſecondly, that the *Potentia* or force of the Pillar A P, is juſt equal to the *Pondus* of the Pillar E C A: Item, that the *Potentia* of the Pillar B Q, is equal to the *Pondus* G D B. Thirdly, that the *Potentia* of A P. is moſt exactly equal to the *Potentia* of B Q; and the reaſon is, becauſe their tops A and B, are parts of the ſame horizontal ſurface. I ſay then, if A P be equal to E C A, and B Q equal to G D B, and A P, and B Q, equal among themſelves, then muſt E C A be equal to G D B. The ſame Water then, doth not counterpoiſe two Bodies of different weight. I grant E C A to be far heavier, than G D B, while they are weighed in a pair of ſcales, but the one is not heavier than the other, as they are weighed in this *ballance* of *nature*.

From what is ſaid, we ſee firſt, that in VVater there is a Preſſure, and a conſiderable weight. This is evident from the riſing of the Mercury. VVe ſee ſecondly, that Fluids counterpoiſe one another, only according to *Altitude*. Thirdly, that when a lighter Fluid preſſeth up a heavier, there is no more preſt up of it, than is the juſt weight of the preſſing Fluid, becauſe the Mercury E C, is juſt the weight of the VVater that preſſeth upon XYO. That's to ſay, the part of the ſurface C, is no more preſt with the Mercury E C, than the part X, is preſt with the VVater L Z X. Fourthly, if Mercury were 28 times heavier than VVater, only three inches would be preſt up: if it were but ſeven times heavier, the altitude would be at S, 12 inches above C. Fifthly, it's as eaſie for a large part of a ſurface, to ſuſtain a large Pillar, as 'tis for a narrow part, to ſuſtain a narrower Pillar: becauſe A P ſuſtains E C A, as eaſily, as B Q ſuſtains G D B.

Sixthly,

Sixthly, that in Fluids there is a *pondus* and a *potentia*: as is clear from the *potentia* of A P, that sustains the *pondus* of E C A. The VVater likewise that sustains, hath a *potentia*, and the Mercury E C is the *pondus* of it. Seventhly, that there is alwayes equality of weight between the *pondus* and the *potentia*. So is the *potentia* of A P, equal to the *pondus* E C A. Eighthly, that the *pondus* begets the *potentia*. So the weight of the VVater, begets the *potentia* that's in A P. For make this VVater deeper, and you augment the *potentia* of A P. If you subtract from it, the *potentia* of A P grows less by proportion. Or the weight of E C A, may be said to beget the *potentia* of A P. To proceed a little further, let us suppose the Air H E to be removed. In this case, the Mercury rises 29 inches higher than E, or 35 above C; even as high as S. In the narrow Tub it will climb up to K, if you take away the Air I G. This comes to pass, by vertue of the Pressure of the *Atmosphere*, that rests upon L N. From this we gather ninthly, that there is a counterpoise between the Air H E, and the weight of the Air that rests upon L N; and that a slender Pillar of Air, is able to counterpoise a thicker: for H E is far narrower than L N. Tenthly, that the Pressure of the Air, can be communicated thorow divers kinds of Fluids; because the weight that rests upon L N, is sent down thorow the VVater L Z X, and down thorow the stagnant Mercury, and thrusts up the Liquor from A to S, 35 inches. Eleventhly, that a lighter Fluid may be made to press with greater burden, than a Fluid *naturally* heavier; because the weight of the Air upon L N, raises 29 inches of Mercury, but the VVater raises only six. VVe see twelfthly, that Fluids have a sphere of activity, to which they are able to press



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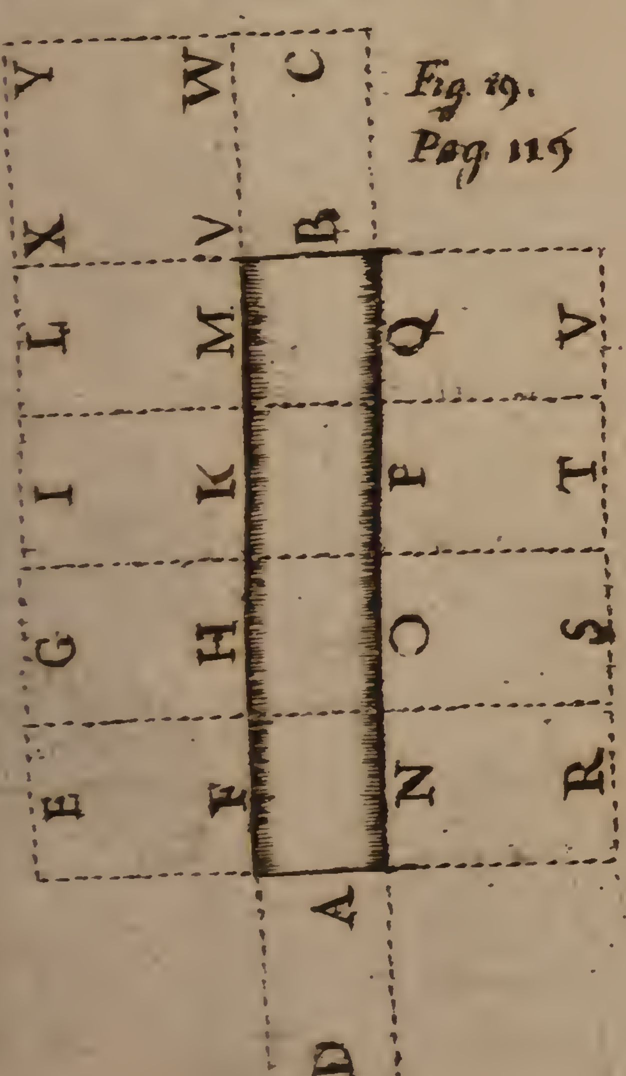

Fig. 19. Pag. 115

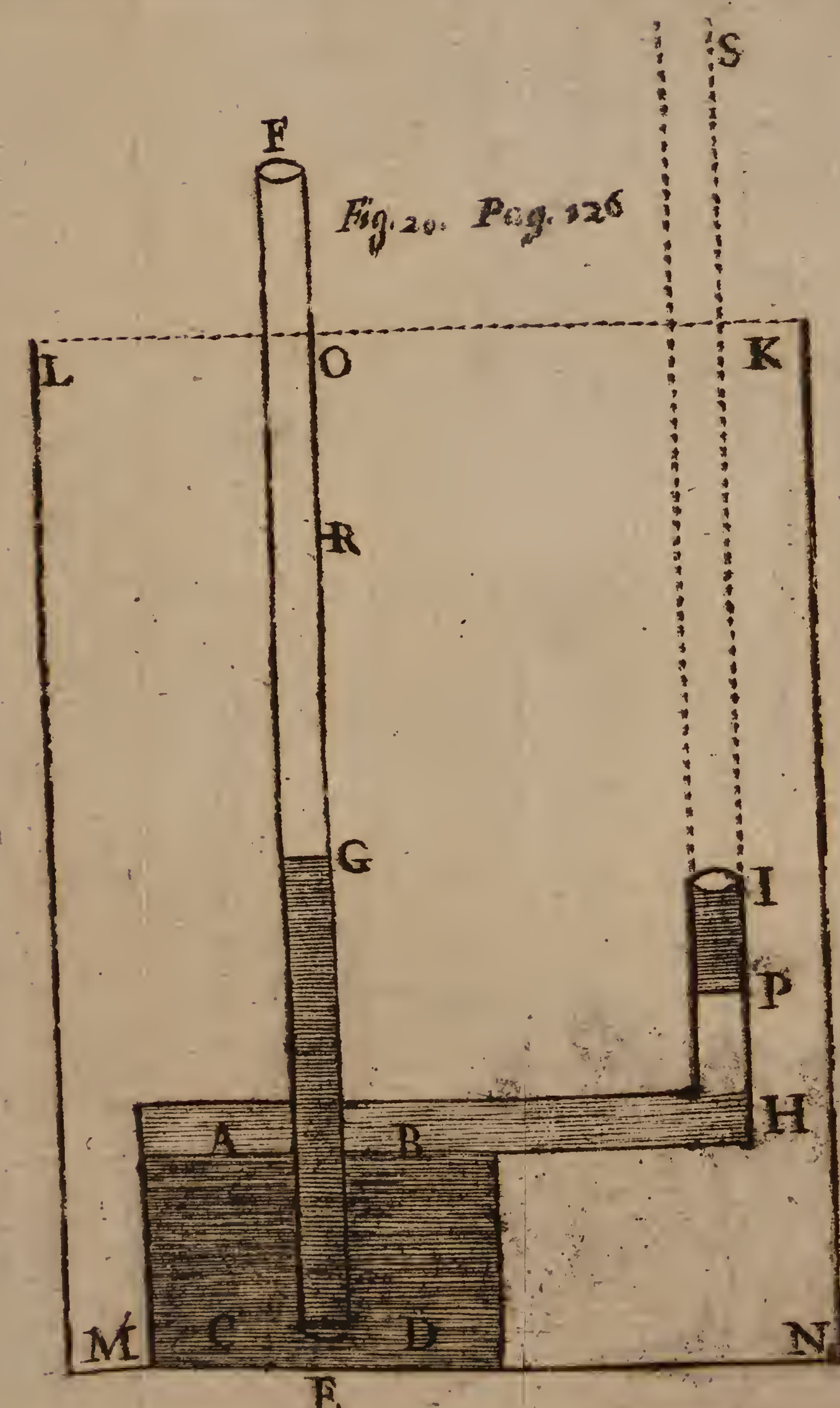

Fig. 20. Pag. 126

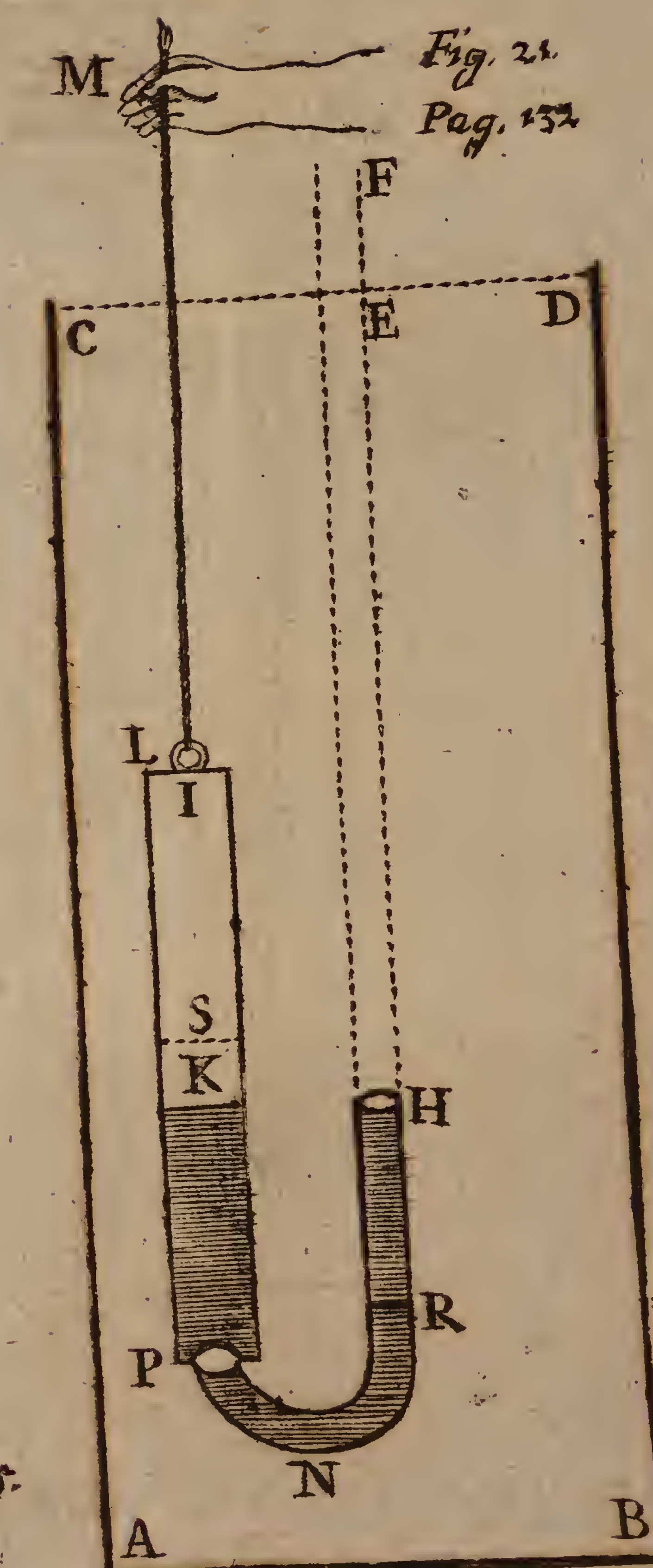

Fig. 21. Pag. 132

Fig. 22. Pag. 137

Plate 5.

preſs up themſelves, or Fluids of different kinds: becauſe firſt, the ſtagnant Mercury can raiſe it ſelf no higher within the Pipe, than it is without. Next, the 84 inches of Water, can raiſe the Mercury no higher than E. Laſtly, the weight of the *Atmoſphere*, can raiſe the Mercury no higher than S, 29 inches above E.

For another trial, take out from among the Water, the two Pipes, and ſtopping cloſely the two under orifices, fill them with Mercury to the brim. Then thruſt them down as before, and open the ſaid two orifices, while they are below the ſurface X Y O, and you will find the whole Cylinder fall down from H to E, and there halt: and the whole Cylinder in the narrow Pipe falls down from I to G. Or, if you pleaſe, before this be done, ſtop cloſely the orifice H, and the orifice I, and you will find the Mercury go no further down than S, by opening the orifice A; and no further down than K, by opening the orifice B. This leads us to a clear diſcovery of the reaſon, why the Mercury ſubſides, and ſinks down from the top of the Tub in the *Baroſcope*, to the 29th inch, whatever the diameter of the Pipe be. And this lets us ſee, that the Mercurial Cylinder is ſuſpended by the Air, after the ſame manner, that the Mercury E C is ſuſpended after: and that there is no more difficulty in the one, than in the other.

EXPERIMENT XVII.

Figure 23, 24.

THis Schematiſm repreſents a Water 30 fathom deep. Under the firſt ſurface A, there are ſix imaginary, as B C D E F G, every one whereof, is five fathom below

another. There are here likewise two Glasses, each one 12 inches high, and 5 inches broad, like unto these, wherein Wine, Sack, or Brandy is preserved. The Glass G M hath its orifice G upward. The other Glass is compleatly open below, without a narrow orifice. For making Experiment, take a long chord, as long as the Water is in deepness, and knit the end of it round about the neck of the Glass at G. Take another line of the same length, and fasten it to the bottom of the other Glass at L. Next, for sinking the two Glasses, take two weights of Lead, and fasten the one to the bottom at M, and the other to the open part of the Glass at S, and T. The two weights then, are P and Q, each one of them about 10 or 12 pound weight. These things being done, let first down the Glass G M, till the weight Q sink it five fathom, namely from A to B, and if you pull it up, you will find the bottom covered with Water, from M to I, about four or five inches. Let it down next, from A to C, ten fathom, and you will find more Water in it; even as much as fills it from M to 2, about seven or eight inches. In passing from C D, the Water rises from 2 to 3. If you sink it, from D to E, the VVater rises from 3 to 4. The VVater rises from 4 to 5, when the glass is come the length of F. And lastly, when the Glass is at G, the lowest fathom, the VVater is as high as K. Let down next, the other Glass from A to B, and you will find the Water rise in it from H to 1, four or five inches, as in the other Glass. In going down from B to C, it rises from 1 to 2. From C to D, it rises from 2 to 3. From D to E, it rises from 3 to 4, and so forward, till the Glass come to the lowest fathom, where the Water rises as high as I.

There

There are here several *Phenomena* to be considered. First, that the Water *creeps* in at the orifice G, and fills the under part of the Glass from M to K. Secondly, that *not one particle* of Air comes out, all the time the VVater is in going in. Thirdly, that this Air is compreſt from M to K, nine inches. Laſtly, that the ingreſs of the Water, is according to *unequal proportion*: becauſe while the Glaſs paſſeth from A to B, more VVater *creeps* in at G, and fills the bottom, then in paſſing from B to C. And more in going down from B to G, than in going down from C to D, as is clear from the unequal diviſions 1, 2, 3, 4, 5, 6, For underſtanding the reaſon of the firſt, remember that in this deep Water, there is a Preſſure, and that this Preſſure grows, as the VVater grows in deepneſs. It is then by vertue of this, that the VVater *creeps* in, and fills the bottom of the Veſſel: for in effect, every part being under a burden, and being therefore deſirous to liberat themſelves from it, they take occaſion to thruſt in themſelves, finding, as it were, more eaſe here, than without, the Air within the Glaſs, being under leſs Preſſure, than the VVater without. The ſecond *Phenomenon* is cauſed by the ſtraitneſs and narrowneſs of the hole G: for this entry being no wider, than the thickneſs of a Sack-Needle, the Air cannot go out, while the VVater is coming in; that is, the paſſage is ſo ſtrait, that the one cannot go by the other. This leads us to the reaſon of the third, for if not one *particle* of Air go out, all the while the Glaſs is in going down, then ſurely, the VVater filling between M and K, muſt compreſs the Air, and reduce it from twelve inches to three. But the greater difficulty is, why the ingreſs of the VVater is according to *unequal proportion*. For underſtanding this, conſider, that this

inequality, is not caused by any unequal Pressure that's in the VVater; for if this were true, then there ought to be less Pressure in the surface F, than in the surface E, and less in E, than in D, which is false and absurd. This inequality then, must flow from the nature of the Air it self, that naturally suffers compression after such a manner. 'Tis evident from the compression of Air in *Wind-guns*; for less force is required to compress the first span, than to compress the second: or contrariwise, more strength is required, to compress the third span, than the second; more to compress the fourth, than the third, and so forth. 'Tis evident in all bodies endowed with Bensil, as in the *Spring* of a *Watch*, that requires more strength to bend it, in the end, than in the beginning.

For a second trial, pull up from the bottom of the Water the Glass L I H, and when it comes above, you will find nothing in it. The reason is, because the Vessel being open between T and S, the whole VVater I H, falls down by degrees; but in effect, is really thrust out, by the strong *Bensil* of the comprest Air I L, that now expands it self, when it finds the Glass go up thorow the VVater, whose Pressure is less, and less from the bottom to the top. but the contrary effect follows, when the other Glass is pulled up; namely, the VVater remains within the Glass, and the Air above it, is thrust out by degrees, as the Glass comes nearer to the top. For understanding the reason of this, consider first, that while the orifice G, is level with the lowest surface, where it now is; that's supposed to be 30 fathom deep, there is a real counterpoise between the inclosed Air G K, and the ambient VVater without: for with what force the one strives to be in, with the same force the other endeavours to be out; and because they are in equal

equal terms, therefore the one cannot yeeld to the other. If you pleaſe to give the victory to the VVater, then let the Glaſs go further down: but if you deſire the Air to overcome, then muſt the Glaſs be pulled up. Pull it then up from the place it is in, till it come to F, and you will find a conſiderable quantity of Air come out at G, and after 2 or 3 minuts of time, emerge and come to the top A, in form of round Bells, or Bubbles. The deepneſs and groſeneſs of the Water thorow which the Bubbles come, makes their motion ſo ſlow. The reaſon of this eruption, muſt be leſs Preſſure of Water in the ſurface F, than in the loweſt G, from whence the Glaſs came. Suppoſe then, the loweſt to have ſix degrees of Preſſure, F to have five, E to have four, D three, C two, and B to have one: and ſuppoſing the incloſed Air KG, to be equal in force to the Preſſure of the loweſt fathom, it muſt then have ſix degrees of *Benſil* in it. Put the caſe then, that with ſix degrees of *Benſil*, it come to the ſurface F, that hath but five, it muſt ſurely break forth, and overcome the force and *power* of that ſurface: for 'tis impoſſible that two Fluids can be unequal in force and power, but the ſtrongeſt muſt overcome, and the weakeſt yeeld: therefore, when the orifice comes to F, the Air being ſtronger than the Water, breaks forth; and as long doth this eruption continue, as inequality of power continues between the one and the other. In pulling up the Glaſs from F to E, other five fathom, more Air comes out. The reaſon is the ſame, namely leſs Preſſure in E than in F: therefore, when the incloſed Air, that hath five degrees of *Benſil*, comes to E, that hath but four, it muſt overcome, and ſo long muſt it be victorious, till by expanding it ſelf, it be reduced to the *Benſil* of four. In pulling up the Glaſs from E to D, more Air yet breaks

out,

out, becauſe a ſurface of three degrees of Preſſure, is not able to reſiſt four degrees of *Benſil.* In paſſing from D to C, more Air comes yet out for the ſame reaſon, till in going up to the top, where there is no Preſſure, no more Air breaks out.

'Tis to be obſerved firſt, that the motion of the Air up thorow the Water is but ſlow, the *medium* being thick, and groſs. Secondly, that if the Glaſs be pulled up quickly, from one ſurface to another, or contrariwiſe, let down quickly, it preſently breaks in pieces. This comes to paſs through the ſtrong *Benſil* of the incloſed Air, that muſt have time to expand it ſelf, otherwiſe it breaks out at the neareſt: for it being of ſix degrees of Benſil, and coming quickly to a ſurface of five, there happens an unequal Preſſure, the ſides of the Glaſs being thruſt out, with greater force, than they are thruſt in with. But if ſo be, the Glaſs move ſlowly up, the incloſed Air gets time to thruſt it ſelf out by degrees, ſo that whatever ſurface the Glaſs comes to, there is little difference between the Preſſure of the Water, and the *Benſil* of the Air. The reaſon why the Glaſs breaks in pieces, while it goes quickly down, is likewayes unequal Preſſure upon the ſides: for in paſſing quickly from a ſurface of five degrees, to a ſurface of ſix, the ſides are preſt in with greater force, than they are preſt out with, and the reaſon is, becauſe through the ſtraitneſs of the hole G, the Water cannot win in ſoon enough, to make as much Preſſure within, as there is without. 'Tis to be obſerved thirdly; that if the orifice G be ſtopped, before that the Glaſs be ſent down, it will not go beyond three or four fathom, when it ſhall be broken in peices; though the motion were never ſo ſlow: and this comes to paſs, through the ſtrong Preſſure

of

of the Water. Fourthly, the ſtronger the Glaſs be in the ſides, it goes the further down without breaking: therefore a round *Glaſs Bottle*, will ſink 20 or 30 fathom, before that it be broken with the Preſſure of the Water. If a Veſſel of iron were ſent down, it ought to go much further. An empty *Cask*, or *Hogſhead*, will not ſink beyond ſeven or eight fathom, without breaking, or burſting; yet a Bladder full of wind, knit about the neck with a Pack-Threed, will go down 100 fathom, yea 1000 without burſting.

It may be here inquired, what ſort of proportion is keeped by the *unequal ingreſs* of the Water? I anſwer, it may be known after this manner. Let firſt down the Glaſs one fathom, and having pulled it up again, meaſure the deepneſs of the Water in the bottom, of it. Next, having poured out that Water, let it down two fathom, and pulling it up, meaſure the deepneſs, which you will find more, than afore. Do after this manner, the third time, and the fourth time, till you come to the loweſt fathom, and you will find the true proportion.

From what is ſaid we ſee firſt, that in Water there is a Preſſure, becauſe through the force and power of this Water, the 12 inches of Air that filled the Glaſs, are reduced to three. Secondly, that this Preſſure growes, as the Water growes in deepneſs: becauſe there is more Preſſure in B, than in A, more in C, than in B; and ſo downward. Thirdly, that when Air is compreſt, by ſome extrinſeck weight, the *Benſil* is intended, and grows ſtronger by *unequal proportion*, as is clear from the unequal diviſions, 1, 2, 2, 4, 5, 6. Fourthly, two Fluids cannot ceaſe from motion, ſo long as the *potentia* of the one, is unequal to the *pondus* of the other: this is evident from

from the Water's creeping in at G, all the while the Glaſs is in going down; and from the Air's coming out, all the while the Glaſs is in coming up. Fifthly, that no ſooner two Fluids come to equality of weight, but as ſoon the motion ends: becauſe, if the Glaſs halt at D, E or F, in the going down, upon which follows a counterpoiſe, then doth the creeping in of the Water ceaſe. Sixthly, there may be as much Preſſure in a ſmall quantity of a Fluid, as in the greateſt: becauſe there is as much *Benſil* in the ſmall portion of Air, included between K and G, as there is of Preſſure, and weight, in this whole Water, that's 30 fathom deep. Seventhly, that the *Preſſure* of a Fluid, is a thing really diſtinct, from the *natural weight*: this is evident from the Preſſure of the incloſed Air G K, that's more and leſs, as the Preſſure of the Water K M, is more and leſs, but the *natural weight* is ſtill the ſame, ſeing the ſame quantity remains. Eighthly, one part of a Fluid, cannot be under Preſſure, but the next adjacent, muſt be under the ſame degree of Preſſure: this is alſo clear, becauſe what ever degree of benſil the included Air K G is under, the Water K M is under the ſame. Therefore, when the one is under ſix, as in the loweſt fathom, the other is under ſix likewiſe. And when the one is under five degrees of Preſſure, as in the ſurface F, the other is under as much. Ninthly, *Benſil* and *Preſſure* are equivalent to *weight*: becauſe the Water K M, is as much burdened with the *Benſil* of that ſmall portion of Air above it, as if it had a Pillar of Water 30 fathom high upon it. Tenthly, that the Preſſure of Fluids, is moſt uniform and equal, and that two Fluids of different kinds, may preſs as uniformly, as if they were but one: this is evident from the ſides of the Glaſs, that are not broken

in

in pieces, by the ſtrong *Benſil* of the incloſed Air, and heavy Preſſure of the incloſed Water; and this happens becauſe the Preſſure without, is as ſtrong as the Preſſure within. We ſee laſtly, that *Water does not weigh in Water*, becauſe when a man lets down this Glaſs by the chord, to the loweſt ſurface, he finds not the weight of the Water K M, that's within the Glaſs, but only the weight of the Lead Q. 'Tis certain, he finds not the weight of the Water I H; becauſe it reſts not upon the Glaſs within, but is ſuſtained by 'its own ſurface, the mouth of the Glaſs being downward, and open. When I ſay *Water does not weigh in Water*; the meaning is not, that Water wants weight or Preſſure in it, but that this weight and Preſſure is not found, as the weight and Preſſure of other bodies are found, while they are weighed in Water. For example, a piece of Lead or Gold, hung in the Water by a ſtring, the other end being faſtened to a Ballance in the Air, *gravitats*, and weighs down the Scale; and the reaſon is, becauſe Lead and Gold, are naturally and *ſpecifically* heavier than VVater; but a piece of Metal of the ſame *ſpecifick* weight with Water, or VVater it ſelf, cannot *gravitat* in VVater, or weigh down the Scale of a Ballance; and the reaſon is, becauſe the ſurface of Water upon which they reſt, bears them up with as great weight and force, as they preſs down with. If it be ſaid, that the Water K M, reſts upon the bottom of the Glaſs within; and therefore, if the man above, find the weight of the Glaſs, he muſt find the weight of the Water within it: I anſwer, the conſequence is bad, becauſe the weight of the Water within, is ſuſtained, and counterpoiſed by the weight of the Water without, whereupon the bottom of the Glaſs reſts. That's to ſay, as there is a Pillar of Water K M within

the Glass, that presseth down the bottom, so there is a Pillar of Water without the Glass, whereupon the bottom of the Glass rests, and which bears up both. But the greater difficulty is this, the further down the Glass goes, it grows the heavier, because of more and more Water, that creeps in at G. Now 'tis certain, the weight Q grows not heavier, therefore it must be the Water within the Glass, that makes the increase of the weight; and therefore Water must still weigh in VVater. If this argument had any strength in it, it would prove the weight of the VVater I H to gravitat and weigh likewise; because the further down this glass goes, it grows the heavier, because of more, and more Water, that creeps up from H to I. Now 'tis certain, the weight of Lead B grows not heavier. Behold, the difficulty is the same in both, and yet it were rashness to affirm the Water I H to be found by a mans hand, when he pulls up the Glass with a string, seing it is sustained by its own surface, and not by any part of the Glass. Though this might suffice for an answer, yet because the contrary is mantained by some, and that with a new Experiment to prove it, I shall be at some more pains to vindicat the truth of what I have said.

This new Experiment to prove that *Water weighs in Water*, I found in a *Philosophical Transaction*, of *August* 16. Anno 1669. *Numb.* 50, the Invention whereof is attributed by the publisher, to that honorable and worthy Person Mr. *Boyl*, whose conclusions and trials, I never much called in question, but finding this opposite, and contrary to what I have demonstrated, I shall crave liberty to say, *amicus Socrates*, *amicus Plato*, *sed magis amica veritas*; and shall therefore examine it as briefly as may be. The words of the Publisher are as follows.

The

The Author of this Invention is the Noble Robert Boyl; *who was pleased to comply with our desires, of communicating it in English to the curious in* England, *as by inserting the same in the* Latine *Translation of his* Hydrostatical Paradoxes, *he hath gratified the Ingenious abroad. And it will doubtless be the more welcome, for as much as no body, we know of, hath so much as attempted to determine, how much Water may weigh in Water; and possibly, if such a Problem had been proposed, it would have been judged impracticable.*

The Method or Expedient, he made use of, to perform it, as near as he could, may easily be learned by the ensuing accompt of a Trial or two, he made for that purpose, which among his Notes he caused to be registred in the following words.

A Glass-bubble of about the bigness of a Pullets egg, was purposely blown at the flame of a Lamp, with a somewhat long stem turned up at the end, that it might the more conveniently be broken off. This Bubble being well heated to rarify the Air, and thereby drive out a good part of it, was nimbly sealed at the end, and by the help of the Figure of the stem, was by a convenient Weight of Lead depressed under Water, the Lead and Glass being tyed by a string to a Scale of a good Ballance, in whose other there was put so much weight, as sufficed to counterpoise the Bubble, as it hung freely in the midst of the Water. Then with a long Iron Forceps, *I carefully broke off the seal'd end of the Bubble under Water, so as no Bubble of Air appear'd to emerge or escape through the Water, but the Liquor by the weight of the* Atmosphere, *sprung into the un-replenish'd part of the Glass-Bubble, and fill'd the whole cavity about half full; and presently, as I foretold, the Bubble subsided, and made the Scale 'twas fastned to, preponderate so much, that there needed 4 drachms, and 38 grains to reduce the Ballance to an* equilibrium. *Then taking out the Bubble with the Wa-*

ter in it, we did, by the help of a flame of a Candle, warily applyed, drive out the Water (which otherwise is not easily excluded at a very narrow stem) into a Glass counterpoised before; and we found it, as we expected, to weigh about four drachms and 30 grains, besides some little that remained in the Egg, and some small matter that might have been rarified into vapors, which added to the piece of Glass that was broken off under Water and lost there, might very well amount to 7 or 8 grains. By which it appears not only, that Water hath some weight in Water, but that it weighs very near, or altogether as much in Water, as the self same portion of Liquor would weigh in the Air.

The same day we repeated the Experiment with another sealed Bubble, larger then the former (being as big as a great Hens-egg) and having broken this under Water, it grew heavier by 7. drachms and 34 grains; and having taken out the Bubble, and driven out the Water into a counterpois'd Glass, we found the transvasated Liquor to amount to the same weight, abating 6 or 7 grains, which it might well have lost upon such accompts, as have been newly mentioned. Thus he.

Figure 24.

THe design then of this Experiment is to prove *that Water weighs in Water*; but, it seems, there is here a very great mistake, which I shall make out after this manner. For which cause, let this Schematism 24 represent the Experiment already described. The *Glass-bubble* then is E P F R. The stem is H C: the weight that sinks the Glass is B. The surface of Water under which it is drowned, is A D. The Ballance to which the Glass is knit by a string is N O. And lastly E F R is the Water that came in, and filled the half of the Bubble.

Now

Now I say, it is not the weight of the Water E F R, that turnes the Scales above, and makes an alteration in the Ballance, but 'its only the weight of the *Lead* B, that does it. For evincing this, consider that all heavy bodies, are either lighter in *specie* than Water; as cork, or of the same *specifick* weight with it, as some Wood is, or lastly heavier in *specie* than Water, as Lead or Gold. Now 'tis certain, that bodies of the first sort cannot *weigh in Water*, and the reason is, because they being naturally lighter, their whole weight is supported by the Water, and therefore not one part of them, can be born up by a Ballance above. A piece of Cork that weighs 12 ounces in the Air, weighs nothing in Water, because as soon as it toucheth the surface, the whole weight of it is supported, and therefore cannot affect the Ballance above. But bodies of the third sort, as is clear from experience and reason, does really weigh in Water: And the reason is, because they being naturally heavier than water, their whole weight cannot be supported by it, and therefore some part of them must burden the Ballance, to which the body is knit. A piece of Lead, that weighs 12 ounces in the Air, will not lose above 2 ounces, when 'its weighed in Water; or may be less. But here there is no difficulty. The question then is, in order to bodies of the same *specifick* weight with Water, as some Wood is, or as Water is. I say of such also, that they cannot weigh in Water; and the reason is, because they being just of the same weight, must have their whole weight supported by it; even as one foot of Water, supports the whole weight of the foot above it. It may be evidenced after this manner. Take a piece of Wood, that's lighter in *specie* than Water, and add weight to it by degrees, till it become of the same

ſame weight with Water. Knit it with a ſtring to a Ballance, ond weigh it in Water, and you will find the whole weight ſupported by the Water. And the reaſon is, becauſe, being left to it ſelf, it can go no further down, than till the upper part of it, be level with the ſurface of the Water. Now, the whole weight being thus ſupported, not one ounce of it can burden the Ballance. In a word, the Ballance can never be burdened, unleſs the body that's knit to it, have an inclination to go to the ground; when left to it ſelf, which a body of the ſame weight with Water can never have. I conclude then, if a body of the ſame weight with Water, cannot *weigh in Water*, neither can *Water weigh in Water*, ſeing Water is of the ſame weight with Water. And Therefore the Water E F R, that's now within the *Bubble*, cannot in anywiſe burden the Ballance above; but muſt be ſupported wholly by the Water I K G H, upon which the bottom of the Glaſs reſts. If it be ſaid, that the Glaſs it ſelf is ſupported by the Ballance, becauſe 'its heavier in *ſpecie* than Water; therefore the VVater within that reſts upon the ſides of it, muſt be ſupported likewiſe by it. I anſwer, the whole weight of the Glaſs is not ſupported, by the Ballance, but only a part; the VVater I K G H ſupporting the other part. And this part is juſt as much as is the weight of VVater, that's expelled by the Glaſs. Now, if the ſaid VVater ſupport ſo much of the Glaſs, becauſe it is the juſt weight of ſo much VVater, why ſhould it not alſo, ſupport the VVater within the Glaſs? Seing the VVater within the Glaſs, is juſt the weight of as much VVater, as will fill the ſpace E F R.

I come in the next place to ſhew, that it is the weight of

of the Lead B that turns the Scales, when the VVater comes in at C, and fills the half of the sphere. For understanding this, let us suppose first, the weight that's in the Scale O to weigh six ounces. Secondly, that the Glass takes 12 ounces to sink it compleatly under the surface A D. Thirdly, the weight B to be 18 ounces; namely for this cause, first, that 12 of it may sink the Glass; next, that the other six may counterpoise the six in the Scale O. Lastly, that the VVater within the Glass weighs six ounces. I abstract from the weight of the Glass it self, which is not considerable, seing the most part of it, is supported by the VVater, and not by the Ballance. Now, I say, 'tis six ounces of the weight B that makes this alteration, and turnes the Scales. For if 12 ounces sink the Glass below the VVater, when 'its full of Air, and no Water in it, then surely six are sufficient to sink it, when it is half full. And the reason is, because there is a less *Potentia* or force in six inches of Air, by the one half, to counterpoise a weight of 12 ounces, than in 12 inches of Air. Therefore this Air, being reduced from 12 inches to six, it must take only six ounces to sink it. If this be, then the other six ounces that now wants a party to counterpoise them, must burden the Ballance, and be supported by the Scale: and therefore, to make a new *equipondium* again, you must make the weight O 12 ounces, by adding six to it, that it may counterpoise 12 of B, the other six being counterpoised by the Air E P F. Let us suppose next, this Glass to be compleatly full of VVater, and the whole Air expelled. In this case the Scale O, must have 18 ounces in it, for making a new *equipondium*. The reason is, because there being no Air in the Glass to counterpoise any part of B, the whole weight of it must be

sustained.

ſuſtained by the Ballance, and therefore in the Scale O, there muſt be 18. Now, I enquire, whether theſe 18 ounces, are the *equipondium* of the VVater within the Glaſs, or of the weight of *Lead* B? 'Tis impoſſible it can counterpoiſe them both, ſeing the VVater is now 12, and B 18. It muſt then either be the counterballance of the Water, or the counterballance of the *Lead*. It cannot be the firſt, becauſe 12 cannot be in *equipondio* with 18, It muſt then be the ſecond. Or if theſe 18 ounces in the Scale O, be the counterpoiſe of the Water within the Glaſs, I enquire what ſuſtains the weight of the *Lead* B? The weight of it, cannot be ſuſtained by the Water, becauſe 'tis a body naturally heavier than Water, it muſt therefore be ſuſtained by the Ballance, I conclude then, that *Water cannot weigh in Water*. If it be objected, that this concluſion ſeems to contradict, and oppoſe the Preſſure of the Water, that's been hitherto confirmed with ſo many Experiments. I anſwer, the *Preſſure of the Water* is one thing, and *Water to weigh in Water* is another. The firſt is, when one Pillar of Water counterpoiſes another, or when a Pillar of Water counterpoiſes a Pillar of Mercury, or is counterpoiſed by a Pillar of Air, all which is in order to the *Natural Ballance*, wherein bodies weigh only according to altitude. The ſecond is, when VVater is not counterpoiſed by VVater, or by Mercury, or by Air, or by any other Fluid; but when 'its weighed by a piece of *Lead* or ſtone in an *Artificial Ballance*, for knowing how many ounces or pounds it is of, as if a man ſhould endeavour to weigh the Water E F R by help of the Ballance above, which in effect is impoſſible.

EXPE-

EXPERIMENT XVIII.
Figure 25.

MAke a *Wooden Ark* after this following manner. The Planks must be of Oak, an inch thick. The height 40 inches. The breadth 36. Closs on all sides, and above, and open below. And because the form is four-square, there must be four Standarts of Timber, in each corner one, to which the Planks must be nailed. Four likewise upon the top, crossing the other four at right angles, to which the cover must be joyned. The sides must be plained, and the edges both plained and gripped in all the parts, that the joynings may be closs. Upon the top fasten a strong Iron Ring, as at N, through which must be fastned a Rope, of so many foot or fathom. And because the use of this Engine is for *Diving* under the Water, it must therefore be all covered over with Pitch within and without, especially in the couplings. And because this Instrument cannot sink of its own accord, it must have a great weight of Lead appended to it, for that cause, whereupon the *Divers* feet must stand, while he is in going down. The precise quantity and weight of it cannot be determined; because it depends upon the quantity of the *Ark*, which if large, requires a great weight: if of a lesser size, requires a lesser weight. But whatever the dimensions of the *Ark* may be, the weight of the *Leaden-foot-stool* can easily be found out by trial. This Invention then, is for *Diving*, a most excellent Art, for lifting up of *Guns, Ships*, or any other things, that are drowned below the Water. And it is in imitation of the *Diving bell*, already found out, and made use of with success. It is called a Bell, because of the form, that represents a

Church-bell indeed, being round, wide below, and narrower in the top: only, the matter is of Lead. It seems, it is of this mettal, first, because Lead is weighty, and will therefore easily sink: secondly, because it's easily founded, and will by this means, being of one piece, be free of rifts, and leaks: thirdly, it being of Lead, will be of a considerable strength for resisting the force of the VVater, that ordinarily breaks in pieces Vessels that are weak. I cannot well divine and guess the reason, why first it is round, and next narrower above, than below, unless, because its more easily founded after this way, than after another. This device here described is named a *Diving Ark*; first, because it is of Timber, and next, because it saves a man from being overwhelmed with the Waters. I prescribe it of *Wood*, because of less trouble, and expence in making of it. 'Tis four square, because it contains under this Figure, far more Air, than if it were round; even as much more, as a square Vessel 30 inches wide, contains more than a round Vessel 30 inches wide. Now, the more Air, that's in the Vessel, the easier is the respiration, and the longer time is the man able to abide under the VVater; which two things are of great advantage to this Art. For if by a guess we reckon, how much more Air is in the one, than in the other, we will find in the *Ark*, as before it is described, 30 square foot of Air, but in the *Bell*, though it be 36 inches wide, as well above, as below, yet little more than 23 will be found, which is a considerable difference. But far less must be in it, seing it's narrower above, than below. Besides this advantage, there are others very useful: for being of Wood, it's more tractable. Next, several Knags of Iron may be fastened conveniently to the sides within, to which a man fastning his hands, may keep his body fixed and sure in going

ing down, and coming up. Moreover, if a man were in hazard to be confounded with fear, or lose the right exercise of his senses, and so be in danger of falling out of the *Ark*; or if his feet should slide off the *foot-stool*, and his hands fail him too, a chord knit to one of those, and fastened about his wast or middle, might bring him up, though he were dead. Then, its far easier to cut out a window or two in the sides of it, not very large, but little, as K and I, whereby, they being covered with Glass, a man may see at a distance, what's upon the right hand, and what's upon the left, and what is before. This device is of excellent use, for through the want of it, the *Diver* sees no more, but what is just below him, which sometimes, when he is near the ground, will not exceed the compass of a large Miln-wheel. But if so be, three holes be cut thorow, one on every hand, and one before, he may see as much bounds, and all things in it, as if he were not inclosed, and invironed with a cover. A little schelf likewise may be fixed upon the one side or the other, for holding a Compass with a Magnetical Needle, for knowing how such and such a thing lies in the ground of the Sea. In one of the corners may hing a little bottle with some excellent spirits, for refreshing the stomach, under VVater. Many moe advantages I might name, this Engine being of Timber, but shall forbear; leaving the collection of them to the ingenious Reader, and proceeds to answer some objections, that may be made against it.

First, if this Engine be made of Wood, it will not sink so easily, as being made of Lead. I answer, this difficulty is soon overcome, namely by making the *Foot-stool* the heavier: therefore how light soever it be, a weight may be found to counterpoise it in the VVater. If it be judged

too light in Timber, it may be lined with Lead, especially without. Secondly, if it be of VVood, there must be couplings and joynings in it, and so rifts and leaks in it, through which the VVater may come. I answer, there is less difficulty here, than in the former; because the joynts may be made so closs in all the parts, and may be so covered over with pitch, or with some such like matter, that it may defie either Water to come in, or Air to go out. Thirdly, if it be made of VVood, it will be in hazard of breaking by the force of the VVater: for oft times its found, that the strongest *Hogshead* will burst asunder by the Pressure of it, if they go but down 7 or 8 fathom. I answer, this objection flows from the ignorance of the nature of Fluid bodies. If so be then, that a man knew, that the Pressure of VVater is uniform, most equal, and presseth upon all the parts of a body within it alike, no such scruple would occurre. I say then, the Ark, though no thicker in the sides, than a thin sawen dale, will go down, in spight of all the Pressure that's in the VVater, not only 10, but 20, or 30 fathom, without all hazard. And the reason is, because what Pressure soever is without, to press in the sides, the same degree of Pressure is within to press them out. By this means, there is not one part of the VVater, how deep soever, to which the *Ark* may come down, but there will be found as much force in the Air within, as will counterballance the whole weight without, as will be infallibly demonstrated afterwards. This answers a fourth objection, namely if holes be cut out in the sides of the Ark, in stead of windows, the force of the VVater will break the Glasses in pieces, that covers them. There is here no hazard, though the said windows were 12 inches in Diameter: but its not needful they be so large. It's suf-

cient,

ficient, if they be 2 inches wide: for a mans eye near to a hole, 2 inches wide, will see a great way about him. There's a necessity the Glasses be joyned in with cement, that Water may not have access to come in, or Air to go out. In such a case ther's no hazard, that the Pressure of the VVater, will break through the windows, or break the Glasses; because the Pressure of the Air within, being of the same force with the strength of the VVater without, the Glasses are keeped intire. It may be enquired, what hazard would follow, upon supposition a small hole were pierced in the head of the Ark above, when it is going down? I answer, ther's not so much hazard, as a man would think; provided the hole be not wide, but narrow. If it be wide, not only the VVater comes in, but the Air goes out, the one thrusting it self by the other. If the hole be no wider, than the point of a bodkin is in thickness; ther's no danger at all: for by reason of the strait passage; the one cannot thrust it self by the other, and therefore neither the VVater can come in, nor the Air go out. And this comes to pass, by reason, that the Air within, is as strong as the Water is without. Now, if they be both of the same strength and force, why ought the Air rather to go out, then the Water to come in; or the Water rather to come in, then the Air to go out? I am confident, though the hole were as wide, as a man might thrust in his little finger, yet no irruption of Water, or eruption of Air would follow. This demonstrats clearly, that though a small rift, or leak should happen in the *Ark*, yet no hazard or danger would follow thereupon. If it be inquired, whither the greatest hazard is from the ingress of the Water, or from the egress of the Air? I answer, ther's no danger from the coming in of the Water from above; because

caufe as it comes in, it falls down, and fo mingles with the reft below. But if the Air fhould go out, the *Ark* fills prefently full of Water, and drowns the man that is in it.

The next thing confiderable in this *Diving Inftrument*, is the foot-ftool of Lead C D, that's not only ufeful for a man to fet his feet upon, when he dives; but efpecially for finking of the *Ark*. For this being made of Timber; and full of Air, cannot of 'its own accord go down, unlefs it be pulled; and forced by fome weight. It may either be broad and round, or fquare: if fquare, a large foot over from fide to fide, or 16 inches will determine the breadth. By this means, it will happen to be pretty thick, feing a great quantity of Lead is required. In each corner, there muft be a hole, for four chords, by which it is appended to the mouth of the *Ark*. Between it, and the roof within, muft be the height of a man and more. The weight of it, cannot be well determined without trial; feing it depends upon the dimenfions of the Ark. Firft then try, how much weight, will bring the top E F G H level with the furface of the Water. When this is found, add a little more weight till it begin to fink, and this will furely take it to the ground, though it were 40 fathom. 'Tis to be obferved, that when the top E F is level with the furface, there is here a juft counterpoife, namely between the *Lead foot-ftool* on the one part, as a *pondus*, and the *Ark* on the other part, as a *potentia*; for with what force the *Ark* endeavours to pull up the *Lead*; with the fame force ftrives the *Lead* to pull down the *Ark*. Hence it is, that as a fmall weight will turn a pair of Scales, when they are in *equilibrio*; fo a fmall weight added to the *foot-ftool* will fink the *Ark*. Though it may feem difficult to determine the juft weight of the foot-ftool, without trial

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as I said, yet I purpose to essay it. For this cause consider that there is no Vessel of VVood almost, if it be once full of Water, but the orifice of it will ly level with the surface of the VVater, wherein it sweems. This proposition is so evident from experience, that it needs no confirmation. From this I gather, that as much weight of Lead or Stone will bring the top of the Ark E F G H, level with the surface of the VVater, as is the weight of the Water, that fills it. If you suppose then the Ark to be 36 inches broad, and 40 inches high, it must contain 30 cubique foot of Water. Now, supposing each square foot of this Water to weigh 56 pound, 30 foot must weigh 1680 pound. This is gathered from trial and experience, for after exact search, I found a cubique foot of Water, in bulk about 16 pints of our measure, to weigh 56 pound. Take then a piece of Lead of that weight, and you will find it make a just counterpoise with the Ark. If any be desirous to know the quantity of it. I answer, if lead be 13 times naturally heavier then Water, you will find that a piece of Lead about 16 inches every way will do it. If it be objected, that when a mans body is within the Ark, the weight of the foot-stool must be less, even as much less, as is the weight of the man, whom I suppose to weigh 224 pound, or 14 stone. I answer, the whole weight of the man is not to be deduced from the foot-stool, but the one half only, and the reason is, because a mans body being of the same specifick and natural weight with Water, it cannot preponderat or weigh in VVater, because magnitudes only naturally heavier then VVater weigh in VVater, as Lead, or Stone; therefore seing the one half of the man is within the Ark, and the other without among the Water, that part only

must

must weigh, that's invironed with Air. This may seem a plausible answer, and might do much to satisfy these, that are not very inquisitive, yet, being examined, it will be found unsufficient. Therefore, I say, there's not one part of the mans body, that weighs within the Ark, or makes it heavier. Yet, I affirm, that when the mans body is within the Ark, a less weight will sink it, then when his body is out of it, even as much less than before, as is the just weight of the one half of the man. For example, if 1680 pound be the just counterpoise of it without the Man, then after the Man is in it, it will take only 1568 pound to counterballance it, supposing the one half of the man to weigh 112 pound, or seven stone: yet it is not the weight of the man that makes this difference. For understanding what's the cause of this alteration, consider, that when a mans body is within the Ark, there is less Air in it, then while his body is out of it, even as much less in quantity, as the bulk of the parts are, that are within. If this be, then must the Ark become heavier, not because the mans body makes it heavier, but because there is less Air, in the Ark, then before, and therefore, there arises an inequality between the weight of the foot-stool and the weight, or rather lightness of the Ark. For if 1680 pound of Lead, was the just counterballance of it, when it had 30 cubique foot of Air within it, it must exceed, when there is less Air in it. But there occures, here two difficulties, the first is, what's the reason, why as much weight must be deduced from the foot-stool, as is the the precise weight of the one half of the man? Secondly, how shall we come to the true knowledge of that weight; that is, to know distinctly how many pounds or ounces it is of? For answer, let us suppose, that the one half of the

the man, is juſt as heavy, as ſo much Water equal in bulk to his own half. This may be granted without ſcruple, ſeing a mans body is judged to be of the ſame ſpecifick, and natural weight with Water: and though there ſhould be ſome ſmall difference, yet it will not make, or produce any inſufficiency in the argument, for theſe demonſtrations, are not Mathematical but Phyſical. Therefore, as much Water in bulk, as is equal to that part of the man, that is within the Ark, muſt be as heavy, as the half of the man. Now ſuppoſing the half of the man, to weigh 112 pound, and conſequently that Water, to weigh as much, I affirm the ſaid Water to contain 3456 cubique inches: but 3456 cubique inches, makes exactly two cubique feet, which I gather thus. Seven pound of Water requires 216 cubique inches, becauſe a Cube of ſix inches, weighs exactly ſeven pound, therefore according to the rule of proportion, 112 pound will require 3456 inches, which amounts to two cubique foot. The Ark then by receiving the one half of the mans body, loſeth two cubique foot of Air, therefore if 30 foot of Air, require 1680 pound weight of Lead to counterpoiſe it, 28 foot of Air, muſt require only 1568 pound: therefore to make a new counterballance, you muſt deduce 112 pound from the foot-ſtool. This anſwers both the difficulties. If it be ſaid, that the foot-ſtool weighs leſs in VVater than in Air, therefore it muſt be heavier, then 1680 pound. I anſwer, 'tis needful to abſtract from that difference, till the juſt calculation be once made, and that being now done, I ſay, that a Cube of Lead 16 inches weighing 1680 pound, (If Lead be 13 times heavier than VVater,) will loſe about 130 pound. The reaſon is evident, becauſe a heavy body weighs as much

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lefs in VVater than in Air, as is the weight of the Water it expells. But fo it is, that a Cube of Lead of 16 inches expells a Cube of VVater 16 inches: But a Cnbe of VVater 16 inches weighs 130 pound, which I gather thus. 216 inches,or a Cube of fix inches, weighs feven pound, therefore 4032 inches, muft weigh 130 pound. For if 216 give 7, 4032 muft give 130. But to return. Though there be fmall difficulty to let it down and to fink it 20 or 30 fathom, yet there is no fmall difficulty to pull it up again. And the reafon is this, becaufe the further down it goes, the Air within, is the more contracted, and thruft up, by the Preffure of the Water,towards the roof. By this means,though near the top of the Water, there was little difference between the weight of the *Lead* and the *Ark*; yet 9 or 10 fathom down, the difference is great, the weight of the one,far exceeding the weight of the other,and therefore there muft be greater difficulty to pull it up from 10 fathom,than from 5: and yet more difficulty from 20 than from 10. However, yet 'tis obfervable that, as the *Ark* in going down, becomes heavier and heavier, fo in coming up, it growes lighter and lighter: therefore lefs ftrength is required, in pulling it up from the tenth to the fifth fathom, than from the fifteenth, to the tenth: the reafon is, becaufe in coming up, the Air within expands it felf, and fills more fpace in the Ark, which in effect makes it lighter, and more able to overcome the weight of the *Lead*. To make thefe things more evident, let us fuppofe, that when the *Ark* is down 18 or 20 fathom,the Air to be contracted by the force of the Water, from L M to P Q 12 inches. Next; that the weight of the *foot-ftool* is 1680 pound. Now, if this weight was the juft counterpoife of the *Ark*,

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at the top of the Water, then surely it must far exceed it now, when it's 20 fathom down, because the Air that was 30 foot, is now reduced to 21. Count then, and you will find, that if 30 require 1680, 21 will only require 1176: therefore the weight of the *Lead*, will exceed the weight of the *Ark*, at 20 fathom deep, by 504 pound. This will be yet more evident, if we consider, that while the top of the Ark E F G H, is level with the surface above, the VVater thrust out of 'its own place by this bulk, is just the weight of both *Lead* and *Ark*. But when 'its down 20 fathom, and the Air reduced from L M to P Q, there cannot be so much VVater expelled now as before, seing the space L M P Q is full of VVater. Now, I say, the *Lead* at 20 fathom, must be exactly so much heavier than the *Ark*, as is the weight of the said VVater L M P Q, which in effect will be 504. pound: for 'its a square body, 36 inches in thickness and 12 in deepness. The weight of the rope is likewise to be considered, that lets down the *Ark*: for the longer it be, and more of it goes out, it's the heavier, and more trouble-some to pull up.

There is no way to cure this difficulty, but by finding out a way, how to keep a just counterpoise between the *Lead* and the Ark, all the time it is in going down. If the Air within did not contract it self, no difference would happen: but this is impossible, so long as the Water is under a Pressure. The expedient then must be found out another way, namely by kniting a small rope to the iron ring N, in length with the other, to which at certain distances, relating to the fathoms the *Ark* goes down, must be fastned empty little Vessels of Wood, or bladders, which by their lightness, may compense the decrement

and decreasing of the Air. First then; let down the *Ark* three fathom, and see how much it is heavier than before: and as you find the difference, so fasten to R one Bladder, or two, till the *Ark* be brought near to a counterpoise. Secondly, let it go down other three fathom, and observe that difference also, and accordingly fasten to T as many, as will reduce the two to a counterpoise again. Do after this manner, till it sink 15 or 20 fathom. 'Tis to be observed, that the further down the Ark goes, the difference is the less: therefore less addition will serve: and the reason is, because there is less Air contracted, in passing between the fifth and the tenth fathom; than in passing from the first to the fifth. The proportion of contraction is represented by the unequal divisions within the mouth of the Ark, as 1. 2. 3. 4. In a word, by what proportion the decrement of the Air is, by that same proportion must the addition be, upon the rope S N. Suppose then, the Air to be diminished four inches, in going down four fathom, which will be 5184 square inches, or three square foot, then surely as much Air must be added to the rope S N, by bladders. In going down as far, let us suppose three inches to be contracted; then less will suffice. Though it cannot be determined without trial, how much Air is contracted in three fathom, and how much in six, and how much in nine; yet this is sure, that the decreasing is according to unequal divisions, that's to say, less in six than in four, less in 8, than in six, and less in 10, than in 8, and so downward: and that this is the rule, namely according to what quantity, the Air within the Ark is contracted, according to that same measure, must the addition of Air be to the rope. If it be said, that Bladders full of wind, cannot go down thorow the VVater without burst-

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ing. I answer, 'tis a mistake, because their sides being pliable, and not stiff like the sides of a Timber Vessel, they yeeld, and therfore cannot burst. It's observable that when a bladder goes far down, the sides becomes flaccid and flagging: In this case, the Air, that before, had the forme of the Bladder, and was somewhat ovall, must now become perfectly globular, and round: for 'tis sure, that the dimensions of it are altered by the Pressure of the VVater, namely from more quantity to less: if this be, then the form must be round, seing the Pressure of the Water is most uniform; even as drops of VVater, or Rain from a house side are round upon this account. This second way, may be thought upon also. Make the *Leaden foot-stool* that sinks the *Ark*, not of one piece, but of many, that so, when the Air within it, begins to be contracted by degrees, in going down, a proportionable weight may be subtracted, for keeping a just counterpoise, all the while of the descent. Or because the greatest trouble is in bringing of it up, let the *Diver*, when once he is at the bottom, subtract so much weight from the foot-stool, as he thinks will go near to make a counterpoise, at that deepness. For example, if the weight of the foot-stool be 40 pound heavier than the Ark, then let him subtract 30 or 36, which may ly, and rest upon the ground, till it be drawen up, at a convenient time, by a chord. By his means it will be easie to move the *Ark*, from one place to another. Next, there shall be little or no difficulty to pull it up. Nay, upon supposition, the rope were broken, by which it was let down, yet if the *Diver* please, he may come up without any mans help. And this is most easily done, namely by subtracting as much weight, as will make the Ark the stronger party. 'Tis to be observed, that

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when you are at the bottom, and if you make the *Lead* but one pound lighter than the *Ark*, it will ſurely come up, and cannot ſtop by the way. The reaſon is, becauſe a very ſmall weight will turn the Scales,between two bodies, thus weighing in VVater. Next, the further the *Ark* comes up, it becomes the lighter, becauſe the Air within it, expands it ſelf the more. But leaving this, let us come to explicat the reaſon, why the contraction of the Air is not uniform, but rather difform. For if in going down three fathom, three inches be contracted, there will not be other three contracted in going down the ſecond three, but leſs: and yet leſs in going down the third three. Two things then are to be explicated here. Firſt, why there is a contraction. Next, why it is after ſuch a manner. As for the firſt; the contraction is cauſed by the Preſſure of the Water, which gradually increaſeth from the top to the bottom; as is clear from the laſt Experiment: therefore, there being a greater Preſſure in a ſurface ſix fathom deep, than in a ſurface three fathom deep, the Air within the *Ark*, muſt be more contracted in paſſing between the third and ſixth, than in paſſing between the firſt and third. When I ſay more contracted,the meaning is,that more quantity is contracted to leſs,whereby the *Benſil* of it is more intended; or that the Air is more bended. As for the ſecond, we muſt remember from the laſt Experiment, that the cauſe of this, is not from the VVater, as if forſooth the Preſſure of it, were according to unequal proportion, but from the Air it ſelf, whoſe kind and nature it is, to ſuffer compreſſion after ſuch a way. 'Tis evident in *Wind-guns*, whoſe ſecond ſpan of Air is compreſt with greater difficulty, than the firſt: and the third with greater difficulty, than the ſecond. 'Tis ſo with all

all bodies endowed with Bensil: for ay the longer you bend, you find the greater difficulty. As there is a great disadvantage to the man that *Dives*, from the contraction of the Air, so there is a great advantage to him, from this manner and way of contraction; for if it were uniform, according to the Pressure of the Water, then if three fathom compreſt three inches, six fathom ought to compresse six inches, nine fathom nine inches, and so forward, till by going down, either the whole Air, should be compreſt to no inches, or else very little should remain for respiration.

The next thing to be taken notice of, is that all the while, during the down going of the *Ark*, there is still equality of weight, between the *Pondus* of the Water, and the *Potentia* of the Air, for with what degree of weight, the Water presseth up the Air, with the same degree of force and power, doeth the Air press down the Water. If this were not, it would be impossible for a man to go down; because of pain. For when one part of a mans body, is less preſt than another, there ariseth a considerable pain, which sometimes is intolerable, as is evident from the application of *Ventoso-glasses*. This equality of weight, is the true reason, why respiration is so easie. Yet 'tis to be observed, that a man cannot breath so easily in the *Ark*, under the Water, as above in the Air; not because there is any inequality, between the weight of the VVater, and the force of the Air; but only because the quantity of it is little. For when a man sucks in as much Air, as fills his lungs, the quantity must be diminished: if this be, the Water must ascend by proportion, though insensibly. When a man thrusts out the same Air again, the quantity is increased; if this be, then the Water must subside a little; both which cannot be, with-

without difficulty, ſeing there is a ſort of ebbing and flowing both of the Air and of the Water, in every reſpiration. But it rather ſeems (you ſay) that this difficulty flowes from the ſtrong, extraordinary benſil, that the Air is under. I anſwer, as long as the preſſure of a Fluid is uniform, though in a high degree, yet there can be no trouble in reſpiration; becauſe with what force ſoever, it is driven in upon the lungs, with the ſame force it is driven out again: therefore, though the Air we live in, were as much again bended as it is, yet (as is probable) we would find no more difficulty in breathing than now. There is one thing makes breathing eaſie under the Water, in the Ark, namely this; when a man ſucks in the Air to his lungs, his breaſt and belly goes out, and ſo fills the ſpace deſerted by the Air, that goes in. This makes the ebbing and flowing far leſs.

From this equality of weight between the preſſure of the VVater, and the preſſure of the Air, we ſee good ground to ſay, that though the *Ark*, were no thicker in the ſides, than a thin ſawed dale, yet there would be no hazard of breaking. I am confident, though it were no ſtronger in the ſides, than a wine-glaſs, that's ſoon broken; yet it might go down 40 fathom without hazard, or danger of burſting. This affords good ground likewiſe to make windows in the Ark covered with glaſs: for if the Preſſure be uniform, and equal, its impoſſible they can be broken. The VVater cannot thruſt them inward, becauſe the Preſſure of the Air, is as able to thruſt them outward.

It's certain, the more Air be in the Ark, the more eaſie is reſpiration: therefore its more eaſie to breath, when the Ark is but down 5 fathom, than when it is down 10 or 15. It's probable a man might live within the *Ark*, it being 40 inches deep, and 36 inches wide, at the deepneſs of

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ten fathom, near two houres; whereas if it were round, and narrow above in form of a Bell, he could not continue an hour. It were very easie to try how long other creatures might live in it, for example dogs, and such like, or fowls, as hens, pheasants or doves. They might easily be inclosed from coming out; for though the whole mouth of the Ark were shut up, except as much passage, as would receive a mans fist, yet it will operate, as well that way, as the other. And there, a little door might be made to open, and shut at pleasure. 'Tis observed, that by long tarrying under the Water in the *Bell*, the Air becomes gross and misty, which hinders a man from seing about him. The cause of this, are vapors that come from the stomach, lungs and other parts of the body, especially from the stomach, when the *ventricle* is full of meat. It's not fit then, that a man about to *dive*, should eat too much, or drink too much, especially such liquors as *Sack* or *Brandy*, that beget many fumes and vapors. If a man were necessitated to tarry a pretty while below, fresh Air might be sent down from above, in bottles or bladders, even as much as might fill up the place deserted by the contracted Air. 'Tis observed by some, that have been under the VVater, that their eares have been so troubled, that for a long time, they have found difficulty to hear distinctly. The reason of this must be from the great Pressure, the *tympanum* hath suffered from the imprisoned Air of the *Bell*. The Organ of hearing is soon troubled, especially when a man is near to a great *gun*, when it's fired. And surely, when a man is but 34 foot down, the Air within the Ark, will be of double Bensil: put the case the man go down 68 foot, or 13 or 14 fathom, the Bensil is tripled: that's to say, if the Air above have five degrees of Pressure in it, the Air of the *Bell*, at 68 foot deep, will

have 15 degrees of Preſſure; therefore the *tympanum* of the ear that's but a ſmall and thin *membran*, muſt be ſore diſtreſſed; that is overbended, and preſt inward; even as, while a man ſets upon a drum head a great weight, v. g. a Bullet of Lead or Iron, of 20 or 30 pound, the skin by this, ſuffers an extraordinary Preſſure, whereby it is in hazard to be rent. 'Tis probable, if a man ſhould go very far down, the *tympanum* might be in hazard of breaking, or being rent in two pieces, there being a greater Preſſure upon the one ſide from the Air without, than upon the other ſide, from the internal Air within, which is thought to be within the *tympanum*.

There remains another *Phenomenon* to be explicated, and it's this: the further up the *Ark* comes from the ground of the Water, towards the top, the Water within it, ſubſides and ſettles down more and more, towards the mouth. The reaſon of it is, becauſe the further up, the Preſſure of the Water is the leſs; and therefore the contracted Air gets liberty to expand, and dilate it ſelf, and ſo thruſts down the Water from P Q to L M. In a word, by what proportion the Air is contracted in going down, by that ſame proportion it dilates, and opens it ſelf in coming up. This lets us ſee, as there is diſadvantage in going down, from the contraction of the Air, ſo there is advantage in coming up, from the dilatation of it. Some think, that the coldneſs of the Water is the cauſe, why the Air is contracted in the Ark, ſuch are thoſe, who deny the Preſſure of it. But this fancy is eaſily refuted; becauſe in aſſerting this, they muſt maintain, the further down, the cold is the greater. If this be, then far more Air muſt be contracted, in going down from 10 to 15 fathom, than in paſſing from 5 to 10; ſeing as they ſay, the further down, the

the cold is the greater; and therefore the contraction of the Air must be the greater; that's to say, there must be more quantity of Air contracted in the one space, than in the other. But so it is, that the further down, the contraction is the less. They judge likewise the coldness of the Water to be the cause, why the sides of empty Vessels are broken in going down. But if this be, then a strong Vessel should go no further down than a weak Vessel; seing cold can pierce thorow the sides of the one, as well as thorow the sides of the other. And why is it, that a bladder full of wind will go down 40 or 50 fathom without bursting, yea 100, and yet a stone-bottle or glass-bottle, cannot go beyond 20 or 30? If cold have in it, that power to break the sides of a strong bottle, it must be far more able to burst the sides of a thin Bladder. This difference is clearly explicated from the Pressure of the Water; but I defy any man to shew the difference from the coldness of it. 'Tis to be observed, that in all such Experiments of sinking of Vessels, as *Hogs-heads*, *Barrels*, and *Bottles*, they must be closs on all sides. Therefore, if a man desire to know, how far down a Glass-bottle is able to go without bursting, he must stop the mouth of it exactly, with a piece of wood, and cement.

In setting down the dimensions of the *Ark*, I have restricted them to 40 inches high, and 36 inches wide. But if any man be desirous to enlarge them, or make them less, he may do it. Only 'tis to be observed, that the larger the *Ark* be, the *Foot-stool* that sinks it, must be the heavier. Yet it hath this advantage, that it contains much Air, which is the great perfection of it. One of a lesser size hath this advantage, that it's more tractable, and easier to let down, and to be pull'd up. But these things are

beſt known from Experience, or if a man pleaſe, he may calculate.

As the *Ark* is a moſt uſeful device for profit, ſo 'tis excellent for pleaſure, and recreation, if a man were diſpoſed to ſee the ground and channels of deep VVaters, or were inclined to find out *Hydroſtatical* concluſions, a knowledge very profitable, and which few have attained to. Though it ſeem ſomewhat difficult to enter the *Ark*, and go down below the Water, yet a little uſe will expell all fear. Then, a man may go down with leſs hazard, and fear in the *Ark*, then in the *Bell*, becauſe he may conveniently faſten his hands, to each ſide of the Ark, if need were. He may conveniently ſit, as in a Chair, all the time of down going, and up-coming, by fixing a little ſeat in it: he may have windows to look out at: his body may be ſo fixed, that there needs be no fear of falling out.

If a man were deſirous to make *Hydroſtatical* concluſions, by *Diving* under the VVater, the dimenſions of the *Ark* might be enlarged, ſo that it might conveniently cover a mans whole body, by which means, having much Air in it, a *Diver* might continue under Water half a day, if need were. Let us ſuppoſe then, the hight of it to be 8 foot, and the breadth 3 foot, or more. In ſuch a caſe, a man might continue under the VVater many hours; and yet not one part of his body wet: for if the *Ark* be 8 foot high, and the man 5 foot in ſtature, at the deepneſs of 10 fathom, the Water can ſcarce riſe 3 foot in it. But why may not a man come up every half hour, when he finds difficulty to tarry down in a little *Ark?* I anſwer, he may; but it's trouble and pains to pull him up, and let him down ſo frequently. And it may ſo happen, that through want of Air in a ſmall *Ark*, he be neceſſitated to come up before

before he end his work. And leaving the work imperfect, he may find difficulty in the second down going, to find sometimes the place where he was, or the thing he was about to lift, *v. g.* a chest of Gold. If it be said, that a great weight of Stone or Lead is required to sink an Ark 8 foot high, which will amount to 4032 pound weight. I answer, 'tis so indeed: but here is the advantage; when it is once below the Surface, there's little more trouble, then with an Ark of lesser dimensions; because of the *equipondium* that's between it, and the weight, that sinks it.

In such a Vessel many trials might be made. As first, that of the *Torricellian-Experiment*, which is nothing else, but a Glass-Tub so many inches long, with a *Mercurial* Cylinder in it of 29 inches high, that's supposed to be kept up at that hight by the Pressure of the Air. If this were taken down about 34 foot, 'tis very probable the Mercury would rise other 29 inches. The reason is, because the Air within the Ark, that presseth upon the Surface of the stagnant Mercury, must be under as much pressure again, as the Air above; but the Air above, is able to support 29; therefore this Air must sustain 58. The reason why the Bensil is exactly doubled is this, 34 foot of Water hath exactly as much Pressure in it, as the whole element of Air; therefore, the Air within the Ark, being 34 foot down, must not only have in it the Pressure of the Air above, but the Pressure of the Water likewise: this necessarily follows, because when two Fluids touch, or are contiguous to other, the one cannot be under five degrees of Pressure, unless the other be under as many. According to this reasoning, if the *Ark* go down 68 foot, the Mercury will rise from 58 to 87. If to 102, it rises

116.

116. This reckoning is founded upon this, namely that Water is 14 times lighter than Mercury; and therefore one inch of Mercury requires 14 of Water to support it in a Tub, and therefore, before Water is able to raise 29 inches of it, the Pipe must be 34 foot deep.

For a second trial, blow a Bladder as full of wind as it can hold, and having knit the neck about with a Pack-threed, place it in the *Ark*, and you will find the sides, that hath been stifly bended become flaccid and feeble, as if the one half of the Wind had gone out, and this will come to pass, before the *Ark* can go down eight or nine fathom. The strong bensil of the Air within the Ark is the cause of this: for as the Ark goes down, the Air grows stronger, and so at length becomes of that power and force, that it easily overcomes the force and Bensil of the Air of the Bladder, and reducing it to less room, causes the sides become flagging. In this case, the said Air, that was oval, and had the form of the Bladder, must become round in form of a Globe, because of the uniform Pressure, that it suffers from the Air of the *Ark*. When once the *Ark* is down 14 or 15 fathom, take the same bladder, and blow it stiff with Wind, and knit the neck as afore. And you will find that in the up-coming, the sides of it will burst asunder with a noise. When the Bladder is thus full of Wind, 'tis supposed, that there is a sort of counterpoise between it, and the Air of the *Ark*. But as the *Ark* ascends, the Air of it, becomes weaker and weaker, while in the mean time, the Air of the Bladder suffers no relaxation; therefore, when the *Ark* comes near the surface, there arises a great disproportion between the one Air and the other, as to strength, and therefore the Air of the Bladder being the strongest, rents the sides

in

in pieces, and comes out with a noiſe. Or, blow it but half full of wind, and you will find before, the Ark come near to the top, the ſaid Bladder to be bended to the full.

For a third trial, take a Glaſs, ſuch as they uſe in *Caves*, for preſerving of Brandy, and ſtopping the mouth cloſely, take it down with you in the *Ark*; and you will ſee, the ſides of it break in pieces, before you go down four or five fathom. The ſtrong Benſil of the ambient Air, is the cauſe of this. If you take it down with the orifice open, no hurt ſhall befal it. Or if you ſtop the orifice in the up-coming, you will find the ſame hurt come to it. But here is the difference, in the firſt burſting, the ſides are preſt inward, by the ambient Air; in the ſecond, the ſides are preſt outward, by the Air within the Glaſs.

For a fourth trial, take a round Glaſs-bottle, pretty ſtrong in the ſides, and when it is down with you in the *Ark* 14 or 15 fathom, ſtop the mouth of it exactly, and when it comes above, you will find a conſiderable quantity of Wind come out of it, when the orifice is opened. This evidently demonſtrats, that the Air within the Ark, 12, 13, or 14 fathom down, is under a far ſtronger Benſil then the Air above.

For a fifth trial, let a man apply to his skin a cold *Cupping-Glaſs*, when he enters the Ark; and he will find ſuch a ſwelling ariſe within it, as when it is applied hot by a Chyrurgion. This tumor begins to riſe, aſſoon as the *Ark* begins to go down. The reaſon is evident from unequal Preſſure, the parts within the Glaſs being leſs preſt, than the parts without.

For a ſixth trial, take a common *Weather-Glaſs*; and place

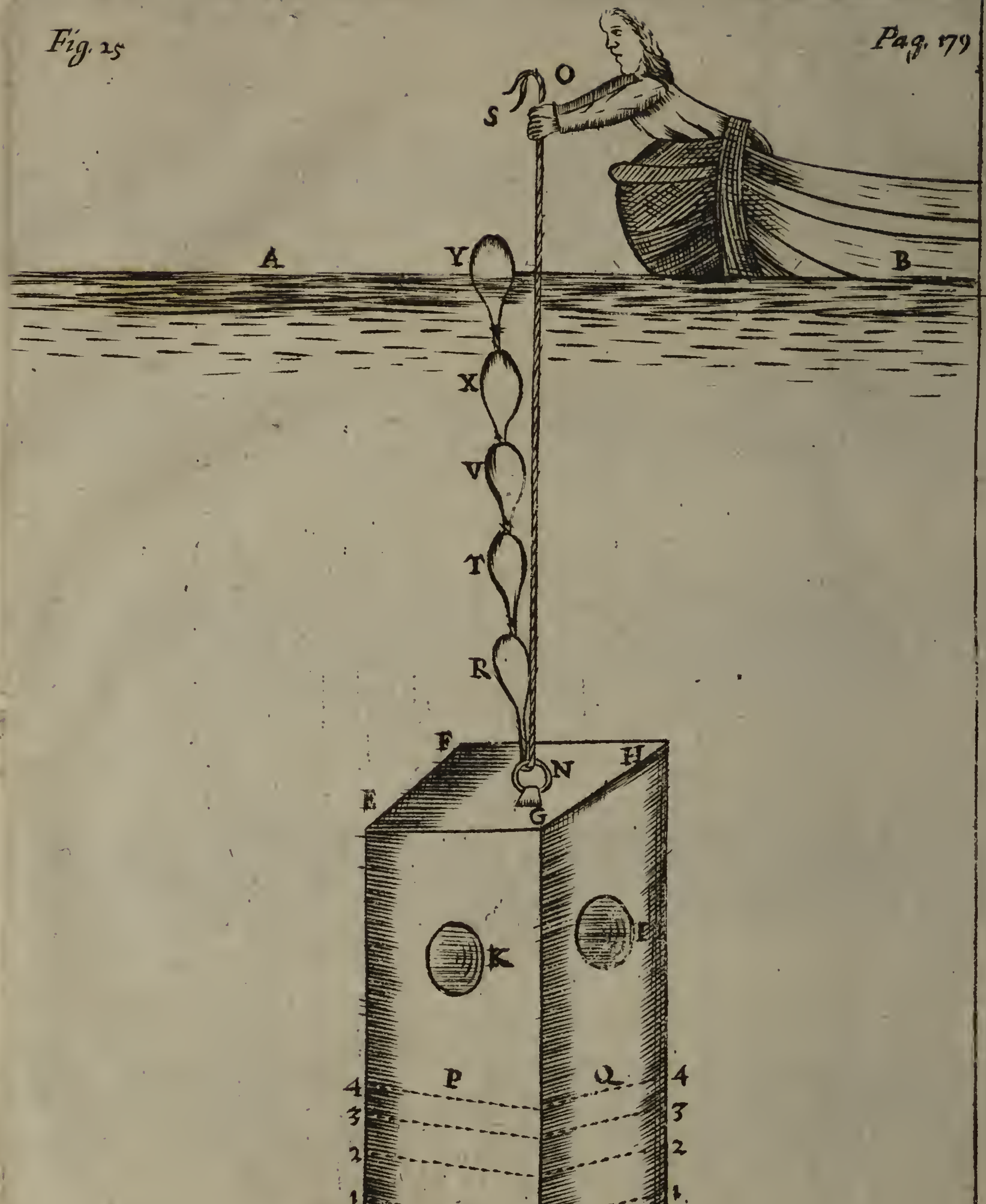
Place it in the *Ark*, and in the going down, you willsee the liquor creep up in it, by degrees, as the *Ark* goes down, as if ſome extraordinary cold, were the cauſe of it. And as the *Ark* comes up by degrees, the ſaid liquor creeps down by degrees. The cauſe of this *Phenomenon* is not cold, as ſome might judge, but the ſtrong Benſil of the Air within the Ark, that ſo preſſeth upon the ſurface of the ſtagnant Water, that it drives it up. If you take with you, a *Weather-Glaſs*, *hermetically* ſealled, no ſuch thing will follow; becauſe the outward Preſſure is keeped off. 'Tis not then cold, that's the cauſe, but weight. By the way take notice, that all common *Weather-Glaſes* are fallacious and deceitful; becauſe the motion of the Water in them, is not only cauſed by heat, but by the weight of the Air, which ſometimes is more, and ſometimes leſs, as frequently I have obſerved, and as hath been obſerved by others. This difference is found,by the alteration of the altitude of the Mercurial cylinder, in the *Baroſcope*, which is more and leſs, as the Preſſure of the Air changeth. In fair weather, and before it comes, the Mercury creeps up. In foul and rainy weather, and a pretty while, before it fall out, it creeps down. Becauſe in fair weather, the weight of the Air is more, than in rainy and dirty weather. *December*, 13. 1669. I found the altitude 29 inches, and nine ten parts of an inch: at this time the heavens were coverted with dry and thick clouds, and no rain followed. *March* 26. 1670. I found the altitude no more, than 27 inches, and nine ten parts, at which time, there was a ſtrong Wind with rain. Between theſe two termes of altitude, I have found the Mercury move near a twelve moneth. 'Tis a moſt ſure prognoſticator, for if after rain,

rain, you find the Mercury creep up in the morning, you may be ſure, all the day following will be fair, notwithſtanding that the heavens threateneth otherwayes. If after fair weather, the Mercury ſubſide, and fall down a little, you may be ſure of rain within a ſhort time, though no appearance be, in the preſent. It falls down likewiſe, when winds do blow. What the true cauſe is, why there is ſuch an alteration in the Preſſure of the Air, before foul weather, and fair, and in the time of it, it is not eaſie to determine.

But we proceed. Trial likewiſe might be made, by firing a great piece of Ordnance above, whether the report would be heard below the Water or not? This would determine the queſtion, whether Water be a fit *medium* for conveying ſound as Air is. Item, whether or not, the Sea water be freſher at the bottom, than near the top, which is affirmed by ſome. Item, whether ſounds be as diſtinct in ſuch a ſmall portion of Air, as they are above. This might be tried with a Bell of a Watch. If need were, a little chamber Bell might be hung within the *Ark*, and a ſmall chord might paſs up from it, through the cover, whereby the perſons above, might by ſo many tingles, ſpeak ſuch and ſuch words to the *Diver*. I have demonſtrated before, that though there were a little narrow hole made in the cover above, yet neither Air would go out, nor Water come in. If a man were curious, he might have a window not only in the ſides, but in the roof above, covered with a piece of pure thin Glaſs, thorow which he might look up, after he is down two or three fathom, and ſee whether there appeared any alteration in the dimenſions of the body of Sun or not, or ſeemed nearer.

We now come to infer some *Hydrostatical* conclusions, as from former Experiments. We see then first, that in Water there is a pressure; namely from the strong *Bensil* of the Air within the *Ark*, that groweth stronger, and stronger, as the Water groweth deeper, and deeper. We see next, that the pressure of the VVater hath an increment: because the further down the *Ark* goeth, the Air is the more bended. Thirdly, two Fluids cannot be contiguous one to another, unless both of them be under the same degree of pressure: because the Air of the *Ark*, and the Water that creepeth up within the mouth of it, are perpetually under the same degree of power, and force, whatever the deepness be. Fourthly, that in Fluids the pressure is uniform; because the Air of the *Ark*, and the Water without, press most equally, one against the other. Fifthly, the more that the Air is bended, it is the more difficult to bend it; and consequently, that the diminution of the quantity, is according to *unequal proportion*. Sixthly, that when the *Ark* is down 34 foot, the *Bensil* of the Air is doubled: and tripled, when its down 68 foot: because the pressure of 34 foot of VVater, is as much as the whole pressure, that's from the *Atmosphere*. If it be enquired, how much weight rests upon the palm of a mans hand, when the *Ark* is down about 68 foot? I answer, the pressure of the Water upon a mans hand, at that deepness with the pressure of the Air above, will be equivalent to the weight of a pillar of Mercury 87 inches high, and three inches thick, which will exceed in real weight 200 pound. If so much rest upon the palm, how much must rest upon the rest of the parts of the body? Let us suppose then, the quantity of the palm, to be found in a mans skin, 200 times, then must he suffer as much

Pressure,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pressure, and actually support as much burden, as will amount to 40000 pound weight. Seventhly, our bodies may be under a huge pressure, and yet that burden not perceptible; as is evident from the *Diver*, who findeth little or no weight, while he is under the Water. Or if there be any Pressure found, it's not comparable to that, which really is. Eighthly, when a man is 14 or 15 fathom down, at every inspiration and expiration, his breast and belly must lift up the weight of 1800 pound: because, if the whole burden be 40000, the weight that rests upon the breast, and belly, will be about 1800. Ninthly, that between every inspiration, and expiration, there happens a perfect counterpoise, namely by the Air, that goeth into the lungs, and the outward Air of the *Ark*: for if the Pressure of the one, were more, than the Pressure of the other, there could be no motion of the lungs. Tenthly, when a man draweth his breath, the Air cometh not in by *suction*, but by *pulsion*. For this cause, though the VVind-pipe were stopped, yet a man might live by having a hole in his side, going into the lungs. Lastly, that there is no such thing as *suction* properly; and therefore the motion of all Fluid bodies, is caused by Pressure and weight. The motion of the blood then thorow the heart, is *driven*, and not *sucted*. Infants properly do not suck, but have the milk squeezed into their mouth. 'Tis evident from the sucking-glass that some women use for milking their own breasts: for by help of this, the Air that guardeth the head of the Pap is removed, and so the Air, that presseth the parts about, and without, squeezes out the milk.

EXPERIMENT XIX.

Figure 26.

THis Figure reprefents a deep Water, whofe firft and vifible furface, is F G. The imaginary furface, is E L C, 34 foot below it. A D B is a *Siphon*, working below this VVater with Mercury. A E L is a Veffel with ftagnant Mercury, among which the orifice A is drowned, the other orifice B exifting among the Water, D M is the hight of the *Siphon* above the line of level, which I fuppofe is 58 inches. For making it work, ftop the two orifices clofely, and pour in as much Mercury at a hole made at D, as will fill both the legs. Then ftopping the faid hole, open the two orifices A and B, and you will find the liquor run as long out at B, as there is any almoft in the veffel A E L. For evincing this, which is the only difficulty, confider, that if this *Siphon*, were filled with Water, and made to work only with Air, (as is clear from daily experience) the liquor would run out conftantly at B. Becaufe there is here an unequal Preffure; the furface of Air N B, being more burdened, than the furface E L C, but where unequal Preffure is in Fluids (according to the 12th Theorem) motion muft follow; I prove the furface N B to be more burdened, than the furface E L C, becaufe the Water B D, is heavier than the Water L D, as is evident to the eye. The Air B therefore, fuftaining far more weight, than the Air E L, muft cede and yeeld. Next, there is here a *pondus* and a *potentia*, the *pondus* is the VVater L D; the *potentia* by which it is counterpoifed, is the Water B D; but thefe are unequal, B D being heavier,

heavier, than L D; therefore according to the 33 Theorem, theſe two Fluids cannot ceaſe from motion. If it be ſaid, that the ſurface N B is ſtronger, than the ſurface E L C, ſeing it is lower. I anſwer, the difference is ſo unſenſible, that they may be judged but one. Now, I ſay, if this *Siphon* work in Air, with Water, it muſt likewiſe, work in Water with Mercury. Therefore, this *Siphon* being 34 foot below the firſt ſurface F G, the liquor muſt run out conſtantly at B. Becauſe, there is here, an unequal Preſſure, the ſurface of VVater N B, being more burdened, than the ſurface E L C. Though there be more weight in N B, than in E L C, becauſe it is lower, yet becauſe the difference is not ſo much, as is between the weight of B D, and the weight of L D, it proves nothing. Note here, that ſo long as D, is within 58 inches of E L C, this *Siphon* will work. The reaſon is, becauſe the Preſſure of 34 foot of VVater, with the Preſſure of the Air, upon F G, are able to raiſe Mercury exactly 58 inches. But if D exceed that hight, no Art will make the liquor run out at B. Note ſecondly, that this *Siphon* will operate with Air and VVater, though the top D were 34 foot above M; and the reaſon is, becauſe the Preſſure of the Air, is able to raiſe a pillar of Water to that hight. Note thirdly, that if there were an orifice opened at C, upon the level line E L C, the two Waters would become of the ſame weight, the one not being able to move the other. If you bore a hole at R, the liquor aſcends from R to D, and goeth down from D to A, and ſo the motion ends. But, if the leg A D were ſix times wider, than B D, the liquor would not run out at B. I ſhall anſwer this in the cloſe.

From this Experiment we ſee firſt, that the motion of Fluid

Fluid Bodies up thorow *Pumps*, and *Siphons* is not for ſhuning *vacuity*, but becauſe they are preſt up violently. We ſee next, that when the Preſſure is uniform, there is no motion in Fluids; but aſſoon, as one part is more preſt, than another, motion begins: becauſe, this *Siphon* will not operate, if the orifice be made in C; but if ſo be, it be in D, then the motion begins; becauſe there is here an unequal Preſſure, which was not in the other. We ſee thirdly, that Fluids have a determinate *Sphere* of *activity*, to which they are able to preſs, and no further: becauſe this Water, is not able to preſs Mercury higher than 58 inches. So the Air cannot raiſe Water higher than 34 foot. If this Water were 68 foot deep, the *Sphere* of it's *activity* would be 116 inches. We ſee fourthly, that in Fluids there is a *Pondus* and a *Potentia*; and that the inequality of weight between the two, is the only cauſe of motion. We ſee fifthly, that as long as this inequality of weight continues, as long continues the motion, becauſe, as long as B D, is heavier than L D, the motion perſeveres. We ſee ſixthly, the poſſibility of a *perpetual motion* in Fluids; becauſe the liquor runs perpetually out at B. If it be ſaid, the motion ends, when the ſtagnant Mercury A E L faileth. I anſwer, this ſtop is only accidental, and not eſſentially from the nature of Fluids. If it be enquired, whether or not, would the Mercury run out at B, upon ſuppoſition, the ſhank L D were twice as wide, as the ſhank B D? I anſwer it would. If it be ſaid that the one is far heavier than the other, namely L D than D B. I anſwer, weight in Fluids is not counted according to thickneſs, but according to altitude.

EXPE-

EXPERIMENT XX.

Figure 27.

THis laſt is for demonſtrating the preciſe and juſt weight of any Pillar of Air, Water, Mercury, or of any other Fluid body, if ſome of their dimenſions, be but once knowen. A B then is a ſquare Pipe 12 foot high, and ſix inches in wideneſs, full of Water, reſting upon the ſurface of Air A C. And E G is a ſquare Pipe 12 foot high, and 12 inches wide, full of VVater, reſting upon the ſurface of Air E F. None needs to doubt, but the two Waters, will be ſuſpended after this manner, even though the orifices A and E were downward, eſpecially if they be guarded with Water, but the demonſtrations, will be the more evident, that wee ſuppoſe the two Pillars of Water to be ſuſpended as they are. From this Experiment I ſay firſt, that the Pillar of Air C D is 168 pound weight, at leaſt; which I prove thus. The VVater A B is 168 pound: therefore the Air C D, muſt be as much. I prove the *Antecedent*, becauſe it's a Pillar of VVater 12 foot high, and ſix inches thick: but every half cubical foot of VVater, that containes 216 inches, weighs ſeven pound: therefore ſeing the Pillar is 12 foot, it muſt contain 24 half feet; but 24 times 7 is 168. The only difficulty is to prove the *Connexion*, which I do thus, from the ſeventh Theor. *all the parts of a Fluid in the ſame Horizontal line*, *are equally preſt*, but ſo it is, that the part A, and the part C, are in the ſame horizontal ſurface; therefore the part A, and the part C, are equally preſt. But if the part A, and the part C, be equally preſt, the Pillar of Air C D, muſt be as heavy; as the Pillar

Pillar of VVater A B. I say secondly, that the Pillar of Air F H, weighs 672 pound, I prove it thus. The Water E G weighs 672 pound; therefore the Air F H, weighs as much. The *Antecedent* is clear; because E G, is a square Pillar of VVater 12 foot high, and 12 inches thick; but every cubical foot of VVater weighs 56 pound: but 12 times 56, is 672. I prove the *connexion*, as before. All the parts of an horizontal surface, are equally prest; therefore the part F, must sustain as much burden, as the part E.

To proceed a little further, let us suppose the Pipe A B to be 34 foot high, and the Pipe E G to be as much: I assert then thirdly, the Pillar of Air C D to weigh 476 pound, which I prove as before. All the parts of the same surface, are burdened with the like weight, but the part A sustains 476 pound, therefore the part C must support as much. The *Connexion* is evident, and the *Antecedent* is so too, because the VVater A B being 34 foot high, and six inches thick, must weigh 476 pound: for, if 216 inches, weigh seven pound, 14688 inches, must weigh 476 pound. I assert fourthly, the Pillar of Air F H to weigh 1904 pound, which I demonstrat by the former *Medium*. All the parts of a Fluid that ly in the same horizontal surface, are equally prest; but so it is, that E and F, do so ly; therefore F must be as much burdened as E; the Water therefore E G, weighing 1904 pound, the Air F H, must weigh as much. For if 216 inches of Water weigh seven pound, 58752 inches (for so many are in the Water E G) must weigh 1904 pound.

Let us suppose secondly, the Tub A B to be only 29 inches high, and the Tub E G, of the same hight, and that

that six inches wide, and this 12 inches wide. I affirm then fifthly, the Air C D to weigh yet 476 pound, and the Air F H, to weigh 1904 pound. Because the Pillar of Mercury A B, weighs 476 pound, and the Pillar of Mercury E G, weighs 1904 pound: therefore, if A B be 476, C D must be as much. And if E G be 1904; F H, must be of the same weight. I prove the Mercury A B to weigh about 476 pound, though it be but 29 inches high; because it is 14 times heavier then Water. For the same cause, doth the Mercury E G weigh about 1904 pound. I say *about*, because 34 foot, containes 29 inches, more than 14 times.

Let it be supposed thirdly, the Pipe E G, (being 34 foot high,) to have the one half of it I G, full of Air, and the other half E K full of VVater, I affirm then sixthly, the part E, and the part F, to be yet equally burdened. That's to say, the VVater E K, that's now but 17 foot, makes as great a Pressure upon E, as when it was 34 foot. The reason of this, is surely the Pressure of the Air I G, that bears down the Water K E, with the weight of 952 pound, the half of 1904 pound. If it be said according to the Theorem 21, that there is as much Pressure and weight in the least part of a Fluid, as in the whole; therefore the Air I G, must be as heavy as E H. I answer I G, is not so heavy as F H, because the Water E K impending in the lower part of the Tub, hath occasioned the Air I G, to expand it self so many inches, by which means, it loseth so many degrees of it's *Bensil*. If you remove the Water E K, then will the Air I G, be as heavy, as F H; because E K being Air, it reduceth I G to that same degree of *Bensil* with it self; but when the Air E is burdened with the Water E K, it can-

not make the Air I G, of that ſame weight with it ſelf.

Let us ſuppoſe fourthly, that only eight foot and an half of Water, are in the Tub, namely between E and N. I ſay then ſeventhly, that the part E, is as much burdened with it, as when the Pipe was full; becauſe the 25 foot, and an half of Air N G, is exactly as heavy, as the 25 foot and an half of the Water that's gone. I prove it thus. The Air E hath the weight of 1904 pound in it ſelf, ſeing the weight of the ſurface, is alwayes equal to the weight of the Pillar, but being burdened with the VVater E N, that weighs 476 pound, it cannot preſs up with more weight then with 1428 pound: and therefore the top of the Water N, muſt preſs upon the under part of the Air, that's contiguous with it, with 1428. If this be, the Air N G, muſt preſs down with as much, ſeing according to the 20 Theorem, it is impoſſible, that one part of a Fluid, can be under Preſſure, unleſs the next adjacent part, be under the ſame degree of Preſſure. Therefore I conclude, that the 25 foot and an half of Air N G, is as heavy, as the 25 foot and an half of the Water that's gone. This makes it evident alſo, that when the Pipe is half full of VVater, as E K, the Air I G, hath the weight of 952 pound. Becauſe E being in it ſelf 1904, but being burdened with E K 952, it cannot make the top of the Water K, preſs upon I with more weight than 952; and therefore (by the 20 Theorem,) the Air G I, muſt weigh 952 likewiſe.

I affirm eighthly, that, when the Pipe is full of Water, from E to G, if a man poiſe it in his hand, he doth not find the weight of the Water E G. And the reaſon is, becauſe it's ſuſtained by the part of the ſurface E. But if the Air E ſuſtain it, my hand cannot ſuſtain it. I find then

then only the weight of the Tub, but not the weight of the VVater within it. I say ninthly, that when I poise the said Tub, I find the whole weight of the Pillar of Air L M, which is exactly 1904 pound. I prove it thus. The *pondus* of a Fluid is then only found, when there is not a *potentia* to counterpoise it, or at least, when the *potentia* is inferior to the *pondus*: but there is here no *potentia*, counterpoising the *pondus* of the Air L M. Therefore, I must find the weight of it, when I lift up the Tub. The *major proposition* is clear from the tenth Theorem. It's evident also, from common experience; for while a ballance is hanging upon a nail, with six pound in the one scale, and nothing in the other, you will find the whole burden, if you press up that one scale with the palm of your hand. But if so be, there were six pound in the opposite scale, you will not find the first six; and the reason is, because it is in *equilibrio* with other six. 'Tis just so here, I must find the weight of the Air L M, while I poise the Tub, because it wants a weight to counterballance it. I prove the *minor proposition* thus. If any thing counterballance the Air L M, it must either be the Air below, namely the part E; or the Water E G: but neither of the twain can do it. Not the Air E, because it hath as great a burden upon it, as it is able to support, namely the Water E G, that weighs 1904 pound. And for this cause, not the VVater it self, seing all the force it can have to counterballance L M, is from the surface of Air E; but this is in *equilibrio* with it already. I said that the Air L M, was exactly 1904 pound weight. This also is evident, because it is just of these same dimensions, with the Air F H. If it be said, the Air LM must be thicker; seing it's equal to the Tub without; but the Air

FH, is only equal to the Tub within. I answer, it is so indeed; but here is a solution to the difficulty. I do not find the whole weight of the Air LM, but only as much of it, as is equal to FH; Suppose the Tub to be 12 inches within, from side to side, and 16 without, from side to side. I say then, I find only the burden of so much Air, as answers to the cavity of the Tub, because the rest of these inches, are counterpoised, by as much below, namely by the Air, that environs the orifice E: for it's supposed, that if the Tub be two inches thick above, it must be as thick in the lips. So that the whole Tub, is not unequally prest; but only so much of it within upon the top, as answers to the cavity. Tenthly, that when the Pipe is but half full of VVater, namely from E to K, I find only 952 pound of the Air LM, though before I found 1904. The reason is, because the one half of it is now counterpoised by the Air IG, and therefore the weight of it becomes insensible. 'Tis clear from the sixth assertion, that the Air IG, presseth down with 952; therefore it must press up with as much, seing according to the sixth Theorem, the Pressure of a Fluid is on every side. Eleventhly, that when there is only eight foot of VVater and a half in the Tub, namely between E and N; I find only 476 pound of the Air LM. Because in this case, the Air NG counterpoiseth 1428 pound of it. For if the said Air, burden the Water NE, with 1428 pound, as is clear from the seventh assertion, it must likewise press up the Tub with as much; and so counterpoise as much of the Air LM. Twelfthly, that when there is nothing within the Pipe but Air, the whole weight of the Air LM becomes insensible to me. The reason is evident, because it is wholly counterpoised by the Air within the Pipe. I affirm thirteenthly, that

the

the VVater E G, is in *equilibrio* with the Water A B: that's to ſay 1904 pound, is in *equilibrio* with 476 pound. I prove it evidently, by the firſt *medium*; all the parts of an Horizontal ſurface, are equally preſt; therefore the part A, ſuſtains no more burden, then the part E; therefore A B, is as heavy as E G, and conſequently, the Air C D, muſt be as heavy, as the Air F H. Leſt this propoſition may ſeem to contradict what is already ſaid, I muſt diſtinguiſh a twofold Ballance, according to the third Theorem, one *Natural*, another *Artificial*. In the *Artificial Ballance*; where magnitudes do weigh according to all their dimenſions, *viz.* *Longitude*, *Latitude*, and *Profundity*, the Water A B, and the Water E G, are not in *equilibrio* together, ſeing the one is 1428 pound heavier than the other. But in the *Ballance* of *Nature*, ſuch as theſe Pipes are, all the four makes an *equipondium* together; becauſe they do not weigh here, according to their *thickneſs*, but only according to their *altitude*. Therefore ſeing A B is as high as E G, and ſeing C D is as high as F H, they muſt all be of the ſame weight.

From the firſt aſſertion I infer, that one and the ſame Fluid, even in the *Ballance* of *Nature*, may ſometimes be in *equilibrio* with a leſſer weight, and ſometimes with a greater, becauſe the Air C D, that weighs really 476 pound, is in *equilibrio* with the Water A B, that weighs but 168. This is, when A B is ſuppoſed to be only 12 foot high. It's likewiſe in *equilibrio* with it, when its 34 foot high. But how can A B, that's 12 foot high, preſs A, with as much weight, as when its 34 foot high? I anſwer by a ſimilitude, when a Cylinder of Wood 12 foot high ſtands upon a Table, it may burden it as much, as if it were a Cylinder 34 foot high. For, ſuppoſing it to be

thruſt

thrust in, between it, and *v. g.* the ceiling of the room above, it must press down with more weight, then if it were not thrust in. So, this Cylinder of Water A B, that's but 12 foot high, being prest between the surface A, and the top of the Tub within, must burden A, as much, as if it were 34 foot high; for being of this hight, it only stands upon the surface, without pressing up the top of the Tub.

I infer from the second assertion, that each Pillar in a Fluid hath a determinate weight. This is evident from the determinate weight of A B, that weighs first 168 pound, being 12 foot high, and 467 pound, being 34 foot high, and so of the rest. I infer secondly, that the thicker, and grosser a Pillar of a Fluid be, it is the heavier, (even in the *Artificial Ballance*) and contrariwise, the more slender and thinner it be, it is the lighter. This is evident from the Water A B, six inches thick, that weighs 476 pound, and from the Water E G, 12 inches thick, that weighs 1904 pound. So doth the Pillar of Air C D, weigh less, then the Pillar F H. Here is ground for knowing the certain and determinate weight of a Pillar, in any sort of a Fluid whatsoever. As to Air, its clear and evident, that a four-square Pillar thereof, 12 inches every way, weighs 1904. That's to say, if it were possible, to take the Pillar of Air F H, in its whole length, from the surface of the *earth*, to the top of the *Atmosphere*, and pour it into the Scale of a Ballance, it would be exactly the weight of 1904 pound. Here is a secret: though that same Pillar of Air, were no longer, than 6 or 10 foot, yet the Pressure of it, upon the body, it rests upon, is equivalent to 1904 pound. If this be, (you say) what is the weight of Air, that rests upon this Table, that's 36 inches

square?

square? I answer, it must be as heavy, as a Pillar of Water 34 foot high, and 36 inches thick, which will, by just reckoning, amount to 17136 pound, or to 1071 stone weight. It may be inquired next, what's the weight of the Air, that burdens the pavement of this parlour, that's 16 foot square? I answer 487424 pound. Because it is exactly the weight of a bulk of Water 34 foot high, and 16 foot thick. 'Tis to be remembred, that though the Pressure of it, be so much, yet being poured into the scale of a Ballance, it will not weigh so much: for not only as much as fills the room must be taken, but as much as passeth from the pavement to the top of the *Atmosphere*. According to this method 'tis easie to determine the weight of any Pillar of Air whatsoever, provided a man but once know the thickness of it, both the wayes, *e.g.* there's a *planum* 12 inches long, and six inches broad, upon which rests a Pillar of Air. The weight of it then is, just the burden of a magnitude of Water 34 foot in hight, 12 inches in length, and six inches in breadth.

Though the weight of any Pillar of Air may be known, by knowing only the dimensions of it, in breadth and length; yet the weight of a Pillar of Water cannot be known, unless all the three common dimensions of it, be first known. The reason is this, the Pillars of Air, are all of the same hight, but the Pillars of Water in the Ocean, are of different hights: therefore, not only must they be known, *secundum longitudinem*, & *latitudinem*, in length and breadth, but *secundum profunditatem*, that is, according to deepness. 'Tis easie to know then, what each particular Pillar weighs. First then, try how much weight is in a cubical foot of Water, and having found this to be *v.g.* 56 pound, you may determine, that a Pillar

Pillar of Water 34 foot high, and 12 inches thick, weighs 1904 pound. A Pillar 34 foot high, and six inches thick weighs 476 pound. Note, that in a Cube of Water six inches thick, there are 216 inches, which weighs seven pound. In a Pillar 12 inches thick, and 20 fathom, or 100 foot high, you will find 5600 pound weight. In one, of the same thickness, but 200 fathom high, there are 56000, fifty six thousand pound weight. In a Pillar three foot square, and 20 fathom deep, there are 50400, fifty thousand, and four hundred pound weight. Make it 200 fathom high with that thickness, and it will weigh 504000, five hundred and four thousand pound. But, if according to the Theorem 25, you consider the weight of the Air above, it will weigh 521136, five hundred, twenty and one thousand, one hundred thirty and six pound. A Pillar 12 foot square, and 300 fathom deep, weighs 12096000, twelve million, ninety and six thousand pound, Lastly suppose there were a bulk of Water 500 fathom deep, and 500 fathom thick, such a magnitude would weigh 8750000000, eight thousand seven hundred, and fifty million of pounds. But if the Pressure of the Air, that rests upon a surface of Water 500 fathom in breadth and length, be taken in, that weighs 119000000, a hundred and nineteen million of pounds, the total, that the bottom of the sea sustains, must be 8940000000, eight thousand, nine hundred and fourty million of pounds, or 558750000 five hundred fifty and eight million, seven hundred, and fifty thousand stone weight.

I infer from the fifth assertion, that the lightest of Fluids may be brought to an *equilibrium* with the heaviest. For though Mercury be 14000 times heavier than Air,

yet the part of the surface A, is no more prest with the Mercury A B, then the part C is prest with the Air C D. Secondly, that *29* inches of Mercury, are of the same weight with 34 foot of Water. Thirdly, the heavier a Fluid be naturally, it hath the less altitude in the *Natural Ballance*; and contrariwise, the lighter it be, it hath the more altitude. This is clear from the Mercury, that's *29* inches, the Water that's 34 foot, and the Air, that's counted *6867* fathom.

I infer from the sixth assertion, that two Fluids of different *gravities*, may make an *equilibrium* with a third of the same kind. Because the 27 foot of Air I G, and the 17 foot of Water E K, are in *equilibrio* with the Air F H. I infer secondly, that 17 foot of Air, may be as heavy as 17 foot of Water, because the Air I G, is exactly as heavy, as the Water E K. I infer thirdly, that the *Bensil* of a Fluid, is a thing really distinct, from the *Natural weight* of it: because the Pressure of the Air I G, is *952* pound; but the natural weight of it will not exceed, if it were weighed in a Ballance, two or three ounces. I infer fourthly, that Air cannot suffer dilatation, but it must lose of it's Pressure. Because the Air I G, that ought to weigh *1904* pound, weighs only *952*. For understanding this, you must know, that when a Pipe is about half full of Air, and half full of Water, and inverted, so much of the Water falls out, and consequently so many inches doth the Air above it, expand it self. So to make this Pipe that's 34 foot high, half full of Air and half full of Water, you must pour in about *19* foot of Water, and the 15 foot of Air that's in it besides, will, when the Pipe is inverted, go up and expand it self to 17 foot, two foot of Water falling out.

I infer from the ſeventh aſſertion; that when there are two Fluids of different gravities, and weights counterpoiſing a third, by what proportion the one grows lighter, by that ſame proportion the other becomes heavier. For, when the VVater E K, that weighs 952 pound, becomes E N, that weighs 476, the Air above it, that weighed 952, becomes now 1428 pound.

I infer from the eighth, that the *pondus* of a Fluid, cannot be counterpoiſed, by two diſtinct *powers*. Becauſe the 34 foot of Water E G, cannot be both ſuſtained, by the part of the ſurface of Air E, and my hand. I infer from the ninth, that the Preſſure and weight of a Fluid, may be found, even in its own Element, by *ſenſe*. Becauſe in poiſing of the Tub, I find the weight of the Air L M. I infer ſecondly, that the *weight* of a Fluid is only found in its own Element, when there is not a *potentia* to counterpoiſe the *pondus* of it, becauſe I find only the weight of the Air L M, becauſe it wants a *potentia* to counterpoiſe it. I infer thirdly, that it is very poſſible even in the *Artificial Ballance*, to weigh a Fluid in its own Element, and to know the preciſe weight of it, to a grain. For this cauſe, take a ſmall chord, and faſten therewith the top of the Pipe G, to the Scale of a Ballance, and the Lead or Stone that makes the counterpoiſe in the oppoſite Scale, is the juſt weight of the Air L M.

I infer from the tenth, that by how much the nearer, the *potentia* of a Fluid, comes to the *pondus*, by ſo much the leſs, is the *pondus* found, or is ſenſible. This is clear, becauſe I find leſs of the weight of the Air L M, it being counterpoiſed with the Air I G, than before. This follows likewiſe from the eleventh aſſertion. I infer from the twelfth, that when the *pondus* of a Fluid, is counterpoiſed,

by

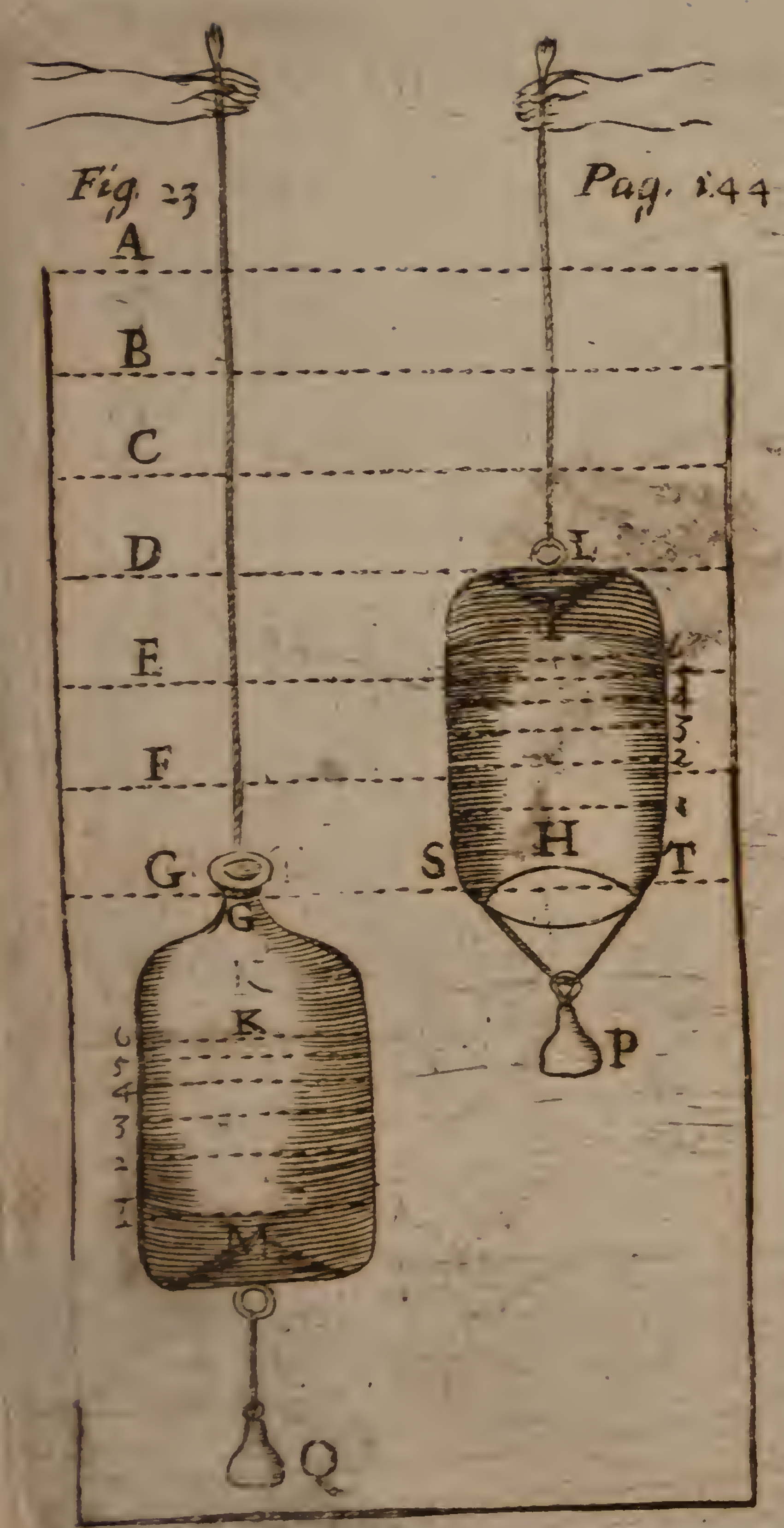

Fig. 23 *Pag. 144*

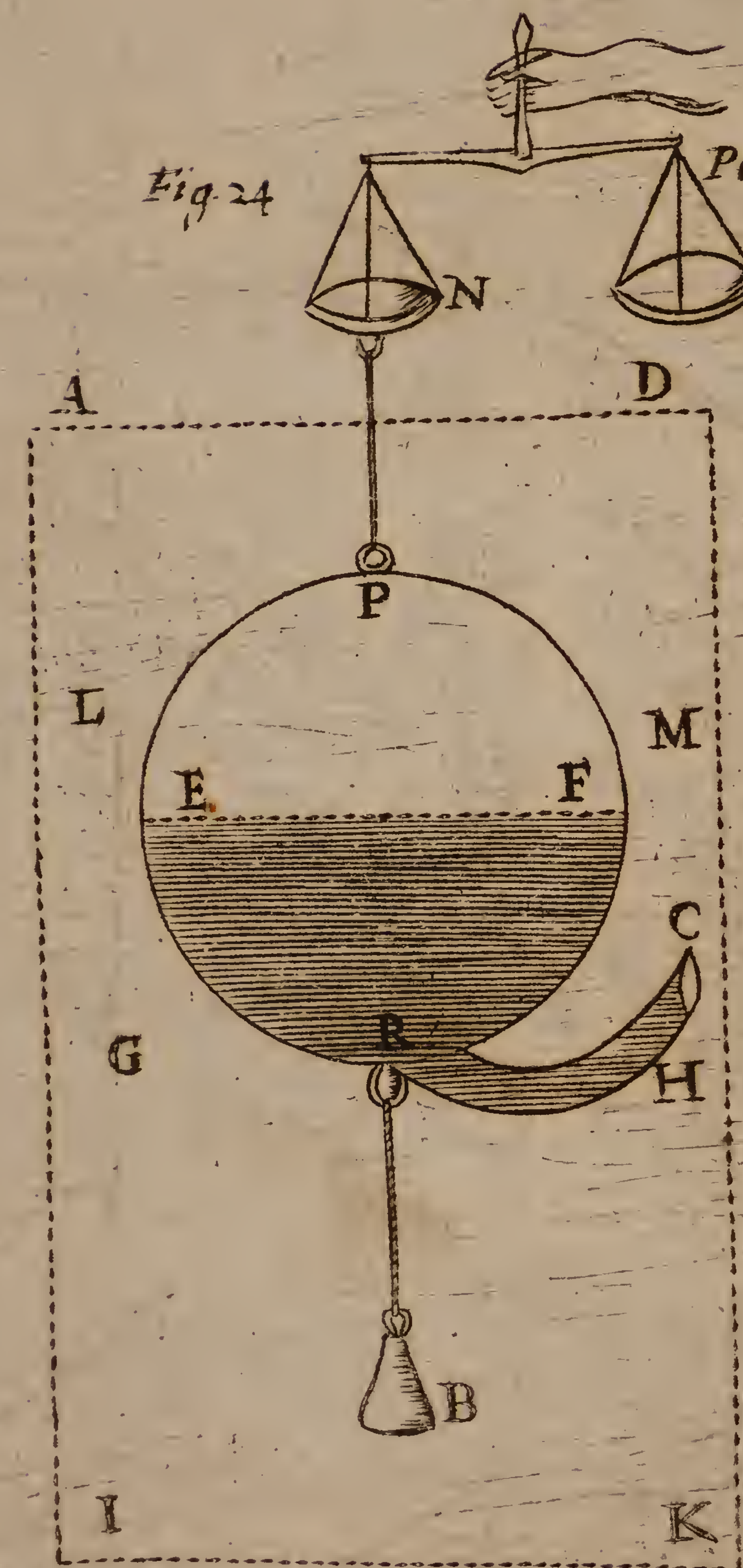

Fig. 24 *Pag. 152*

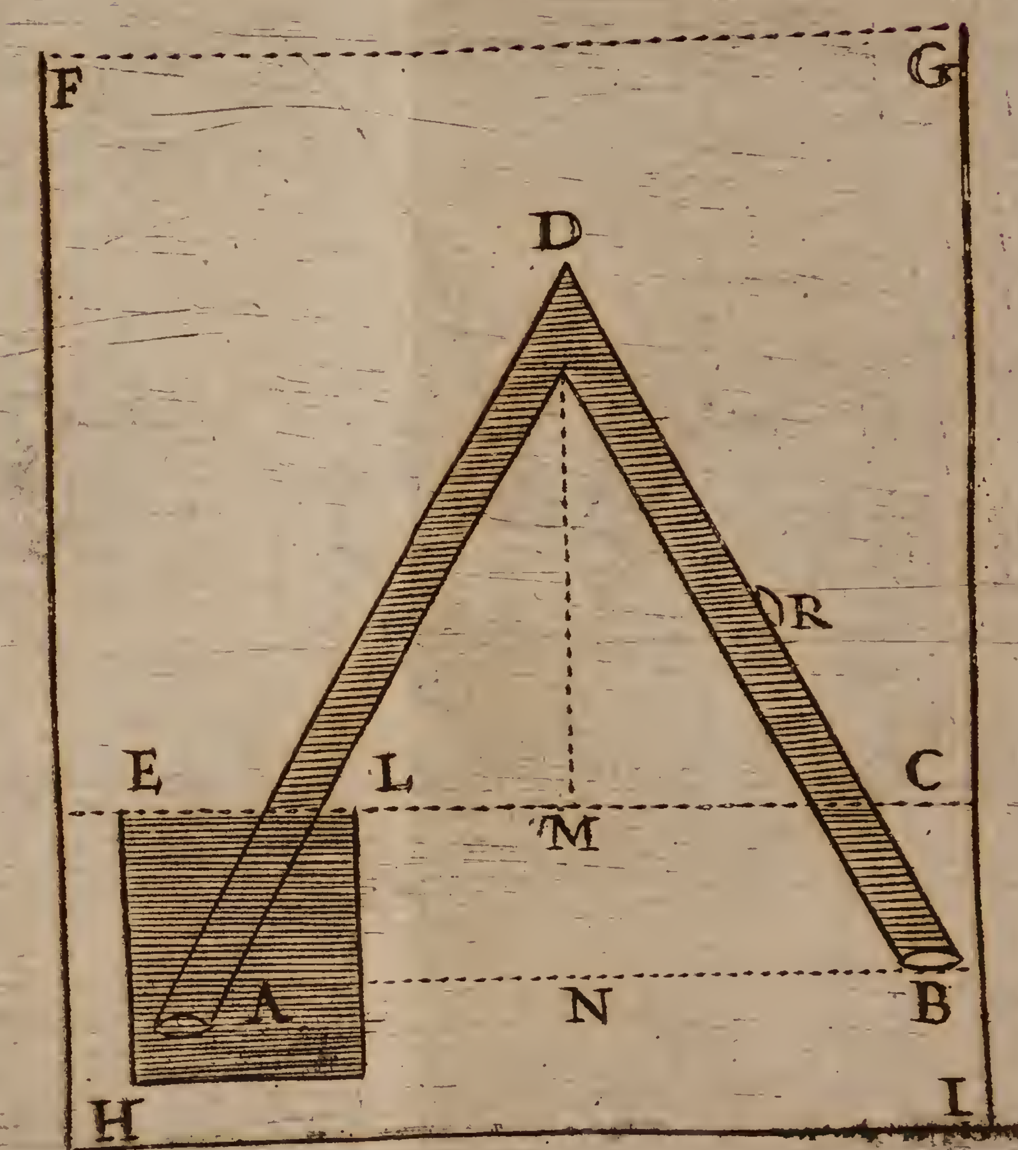

Fig. 26. *Pag. 182*

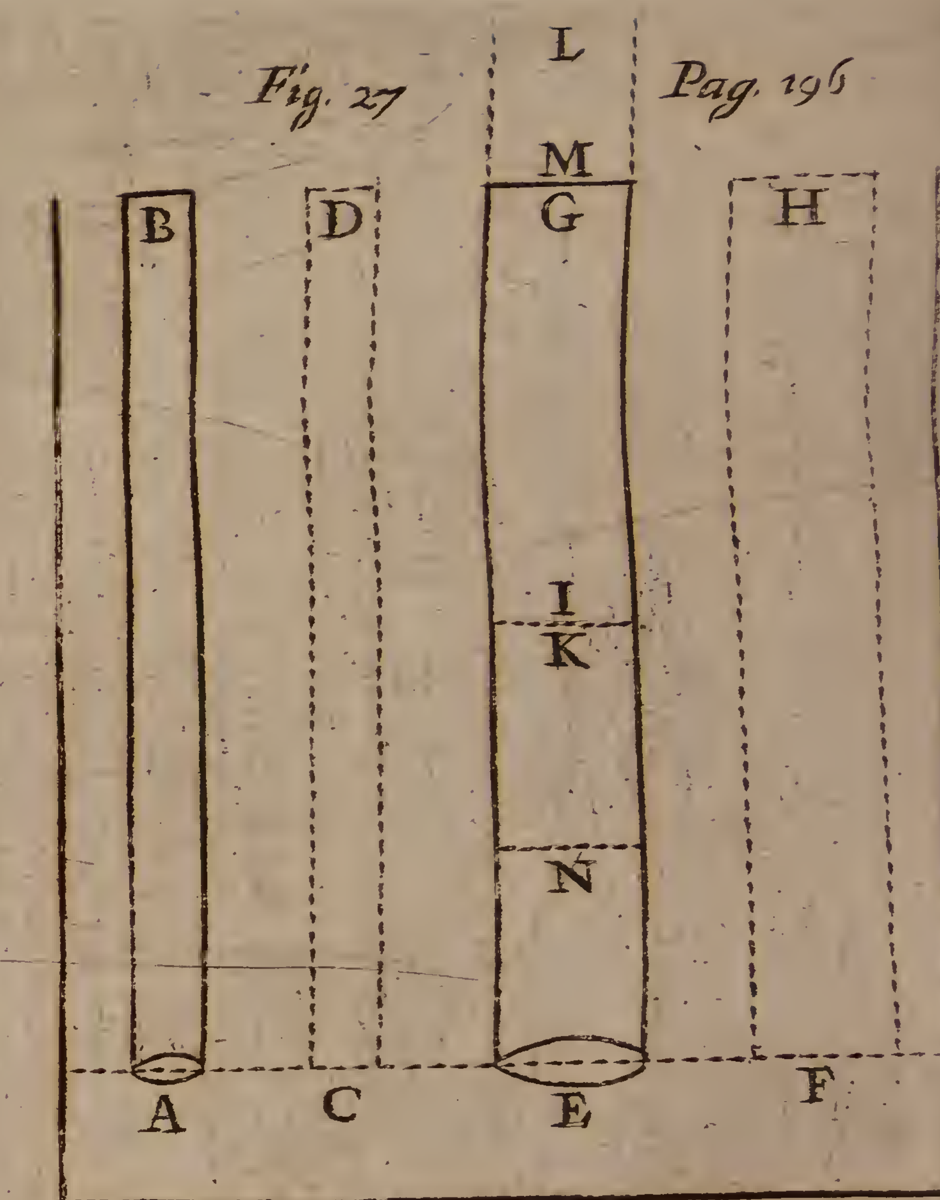

Fig. 27 *Pag. 196*

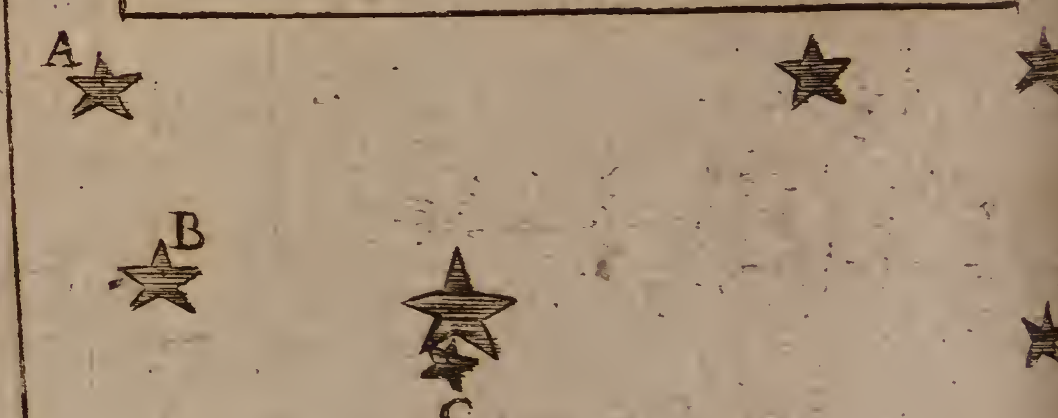

Fig. 28 *Pag. 201*

Plate 6.

by an equal *potentia*, it becomes altogether insensible. I infer from the last, that two Fluids differing in weight, according to the *Libra* or *Artificial Ballance*, may agree in weight, according to the *Natural Ballance*. I infer secondly, that Fluids in the *Ballance* of *Nature*, do not counterpoise one another according to their *thickness*, but only according to their *altitude*.

To put a close to this Experiment, let us suppose the Pipe E G to be 68 foot high, and void of Air. If then the orifice E be drowned among stagnant Water, the Liquor of its own accord (as it were) will rise from E to K 34 foot, the other half I G remaining empty. This evidently shews, that the Pressure of the Air, hath a *Sphere of Activity*, beyond which it is not able to raise or press up a pillar of VVater. 'Tis folly then to think that Water may be conveyed over high places by the help of a *Siphon*, *v. g.* from the one side of a Hill over the top, to the other side. For, if that hight exceed perpendicularly 34 foot, no Art will do it. Yet contrariwise, it is possible to transport Water, by *Pipes* and *Siphons*, not only 34 foot below the *source*, but 3400. Nay, if there were a *Siphon* passing from the surface of the Earth to the Center, and thence rising to the surface again, it would convey Water from the one place to the other. For 'tis a certain and infallible rule in the *Hydrostaticks*, that Water will rise as high in this place, as the hight of the place is, from whence it comes, even though the windings and turnings of the *Lead-Conduits* underground were as a *Labyrinth*, and though this place, were not only 1000, but 5000 pace distant from the other. 'Tis to be observed, that if the mouth of the *Conduit*

here, be exactly as high as the other end at the Fountain, the Water ſtands ſtill. And the greater the difference be, the Water flows out with the greater force. By the help of ſuch *Conduits*, 'tis eaſie to convey Water to a City many miles. Such Pipes are ordinarily made of Lead. But for ſaving expence, they may be made of Timber, or Clay well burnt in an Oven.

AN

AN ACCOMPT OF

Miſcellany OBSERVATIONS,

Lately made, by the Author of the foregoing EXPERIMENTS.

OBSERVATION I.

IN *May* 1669, there was need of a new Sink, on the eaſt ſide of *Tranent*, for winning of *Coals*. But while the *Coal-hewers* were in digging down, and had come the deepneſs of 13 or 14 fathom; they were ſtopped from working by *Damps*, or ill Air, that flowed out plentifully from the ſides of the ſink, wherein there were a great number of *Cutters*, or rifts, out of which that ill Air came. To try the nature and power of *Damps*; I took a dog, and faſtned him in a *bucket*, with a ſmall roap, that he might not leap over, and when he had gone down 7 or 8 fathom, he preſently begins to howl, and cry pitifully, as if he had been beaten

beaten ſore with a rod, and a little after, he begins to ſtagger and his feet failing him, he falls down, as one overtaken with the Epilepſy, and in going down to the bottom, his eyes turning in his head, they appeared very ſhining and clear like two large bright Diamonds. Fearing, that the *Damp* ſhould have killed him out of hand, he was inſtantly pulled up from the bottom, where he had not tarried 15 *ſeconds* of time. And when the bucket had come to the mouth of the *ſink*, he was pulled out, and laid upon the ground, to get freſh Air. When he had lien a while as dead, he begins at laſt to gape, and gaſp, and make ſome reſpirations, as if he had been rather expiring, than recovering. Next, he began to ſtir and move his feet, and after, to raiſe himſelf upon his knees; his head ſtaggering and wavering from ſide to ſide. After a *minut* or two, he was able to ſtand upon his feet, but ſo weakly, that he was not in capacity to walk or run. Yet at laſt, being much refreſhed, he eſcaped from us, and ran home, but ſlowly. In the afternoon, the ſame Experiment was repeated, with another dog, whoſe caſe was the ſame in all things. But after he was perfectly recovered, for a further trial, we let him down the ſecond time, and ſuffered him to tarry in the bottom of the *ſink*, about the ſpace of three minuts: but when he was pulled up, and taken out, we found no ſymptomes of life in him; and ſo after half an hour and more, his body began to ſwell, which ordinarily befalls ſuch, who are killed after this manner. After this, we ſent down in the Bucket, a little Chicken, which, when it came near the *Damp*, preſently flapped with the wings, and falling down, turned over and over for a pretty while, as if it had been taken with a *vertigo*, or giddineſs. But by drawing up the Bucket in haſte, and bringing the Bird to the freſh Air, it recovered. In the

evening.

evening, we let down a *lighted Candle*, but it was soon extinguished, when it came near mid-sink; for here, rather than in the bottom, was the strongest Damp. Lastly, we let down by a chord, a *Brand-iron*, with burning Coals, whose flame was soon put out, and after a little while, we perceived the red Coals to be extinguished by degrees; yet not totally, because, as the Coal-hewers observed, the power of the *Damp* was not so strong, as before. These *Damps* then have their ebbings and flowings, which seem to depend upon the weather, or rather upon the situation of the winds, and their force. For 'tis observed, that a high South-west wind causeth ill Air in this place; and that, by reason of much wast ground, that lies upon the South, and South-west hand of this *Sink*, whence are conveyed under ground by secret passages, which are nothing else but so many rifts and openings, commonly called by the *Coal-hewers*, *Cutters*, corrupted and rotten Air, full of sulphurious stems. The reason why these passages are open, and replenished with nothing, but corrupted Air, is this, the Water, that's ordinarily called the Blood of the Coal, being withdrawn with subterraneous Gutters (commonly called *Levels*) that are digged, and wrought under ground, sometimes a very long way, for drying of the *Mines*, and the veins of the earth being now empty, there succeeds Air; which Air, by process of time, and long standing, rots, and contracts a sulphurious quality, which causeth sudden death. Now, when the wind is high, and strong from the South or South-west, that sulphurious Air is driven through the ground, and coming to *Sinks* and *Mines*, where men are working, presently infects the place, and hinders the work. 'Tis often observed, that the wind and Air under ground, keep a correspondence in their moti-

on, with the wind above ground : and therefore, when the wind is in such a point above, 'tis found, that the motion of the Air below runs such a way, and the contrary way, when the wind above ground, is in the opposite point. When there is a free passage between the bottom of the two Sinks, you may observe the wind come down through the one, and running alongst under the ground, rise up thorow the other, even as Water runs thorow a *Siphon*. For this cause, when the *Coal-hewers* have done with such a *Sink*, they do not use to stop it, or close it up, but leaves it standing open, that the Air under ground may be kept under a perpetual motion and stirring, which to them is a great advantage. 'Tis very strange to see sometimes, how much Air, and how fresh it will be, even at a very great distance, namely four or five hundred pace, from the mouth of the *Sink*. This could never be, unless there were a considerable Pressure and weight in it, whereby it is driven forward, thorow so many *Labyrinths*. And even in the utmost room, where the *Coal-hewers* are working, the Pressure is as great, as it is above ground, which is found by the *Torricellian Experiment*. In such a case, the Air cannot press down thorow the Earth and Metalls, therefore the Mercury must be suspended, not by a Pillar from the *Atmosphere*, but by the *Bensil* of it. Nay, put the case, that the whole Element of Air were destroyed, and this remaining, yet would it be able to support 29 inches. To shut up this discourse, it is observed by the *Coal-hewers*, that when there is ill Air in a *Sink*, a man may perceive distinctly, what is lying in the bottom, so clear and transparent is the Air of it : but when the *Damp* is gone, the *Medium* is not so clear. In temperat and cold weather, the *Damps* are not so frequent. From this *Sink*, in soft winds, or in Northerly winds, or when it blows from East or North-east, the *Damps* are driven away. O B-

OBSERVATION II.

JUpiter upon Wednesday night, at eleven a clock, being 24 of *November*, 1669, had the following position with the stars of *Gemini*. He was so near to the Star C, that to appearance, the points of his rayes did touch it. This Star by looking upon the material Glob, is fixed in the very *Zodiack*, and in the 13 degree of *Cancer*, and is the very navel of the following *Twine*. The Star A is *Castor*. The Star B is *Pollux*. The star D, is fixed in the forefoot of the following *Twine*. From this place he moved, with a retrograde motion, till he came to the 5 of *Cancer*, about the 20 of *February*, 1670, and from that time became *Direct* in his motion, and so upon the 27 of *March*, 1670 at 9 a clock, he was in a right line with *Canis minor*, and the brightest Star in *Auriga*, and was in a right line with the eastmost shoulder of *Orion*, and *Castor* in *Gemini*, or with that Star, when South-west, that's highest, and West-most.

OBSERVATION III.

IT is written in the History of the *Royal Society*, that such a member of it, whose name I have forgotten, hath found out, among many other curious inventions, this, namely a way for knowing the motion of the Sun in *seconds* of time: but is not pleased to reveal the manner how. Because such a *device* may be usefull in Astronomy, and likewise for adjusting the *Pendulum Clock*, I shall therefore briefly shew, the manner and way how such a thing may be done, as I have tried it my self. I took an *Optick Tub*, about 12 foot long, only with two *Convex-*

glasses in it, and did so place it in a dark room, by putting the one end, in which was the *Object-glass*, without the window, and keeping the other within, that I caused the beams of the Sun shine thorow it, which were received upon a white wall four or five foot from the Tub. This image, which was perfectly round, and splendid, did move alongst the wall very quickly, so that in a minut of time, it did advance seven inches and a half, which will be the eight part of an inch in a *second*, a motion very sensible. Now, this beam that came thorow the Tub, and lighted upon the wall, would not have moved one inch in a minut, if it had wanted the two Glasses; for as they magnify, and seem to bring nearer the *object*, so they quicken the motion of it. In a word, by what proportion the *object* is made more, by that same proportion is the motion quickned. 'Tis to be observed, that the longer the Tub be, the motion is the swifter: for as the longest Tub doth ordinarily most magnify the object; so doth it most quicken the motion. Next, the farther distant the white wall is from the end of the Tub, the larger is the image; and contrariwise, the nearer it be, it is the less. Thirdly, the farther the wall be from the end of the Tub, the circumference of the image is the more confused; and the nearer it be, it is the more distinct. Fourthly, the darker the room be, it is so much the better. Lastly, this trial may be made with ordinary *Prospects*, of a foot, two foot, or three foot long, which will really do the thing, but not so sensibly, unless the glasses be very good.

As to the use of this device in Astronomy, I shall not say much. But shall only mention what it may serve for in order to the Pendulum-Clock. For this cause, let a

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man choise a convenient room, with a window to the South, wherein this Tub may be so fixed, that it may ly just, or very near to the true *meridian*, and may move *vertically* upon an axil-tree, because of the Suns declination every day. Then at a certain distance from the end of it, fix and settle a large board of timber, smooth, and well plained, and well whited, for receiving the image. In the middle of this board, draw a circle with Charcoal, equal in diameter to the circle of the image. Now, this being done, you will find that assoon as the west side of the Sun, begins to come near to the *Meridian*, the image begins to appear upon the board, like the segment of a circle, and grows larger, and larger, till it become perfectly round. Now in the very instant of time, wherein the image, and the circle are united, set the wheels of your Clock a going, from the *hour, minut*, and *second* of XII. To morrow, or 3 or 4 dayes after, when you desire to make an examination, wait on about 12 a clock, when the Sun is coming to the *Meridian*, and you will find what the difference is. If the *Clock* go slow, observe, assoon as the image is united with the circle (which you will perceive in a *second* of time) the variation, that's to say, how many *seconds* interveens between that *second*, wherein the union fell, and that *second*, that closes XII hours in the *Clock*. If it go fast, observe how many *seconds* passes from that *second*, that ends XII hours, and that wherein the image of the Sun is united with the circle, which if you do, you will know exactly, what the difference is, even to a *second*. But without this, you will find great difficulty to know the variation in 15 or 20 *seconds*, especially in a common *Dial*. But here, you will see distinctly the image of the Sun move every *second*

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of time, the eighth part, or the ſixth part, or the fourth part of an inch, according to the length of your Tub, and goodneſs of your glaſſes. 'Tis to be obſerved, that in adjuſting the *Pendulum Clock*, reſpect muſt be had to the table of *Equation* of *dayes*, commonly known in Aſtronomy. For if this be not, it is impoſſible to make it go right, and that becauſe all the natural dayes of the year, are not equal among themſelves: that's to ſay, the time that's ſpent by the Suns motion from the *Meridian* this day, to the ſame *Meridian*, the next day, is not equal, but is more or leſs, than the time ſpent betwixt *Meridian* and *Meridian*, a third or fourth day after. For inſtance, the Sun this day being 11 of *July*, comes ſooner to the Meridian by three *ſeconds* of time, than he came yeſterday. Within 9 or 10 dayes, (ſuppoſe the 22 of *July*) he will be longer in coming to the Meridian by 4 *ſeconds*, than upon the 21. This difference I grant, in ſhort time is not ſenſible, yet once in the year, it will amount to more than half an hour. This inequality of dayes ariſes from two cauſes. Firſt, from the Suns *eccentricity*, whereby he moves ſlowlier in one part of the Zodiack, than in another: for in Summer when he is furtheſt from the Earth, he goes ſlowlier back in the Ecliptick, than in Winter, when he is nearer to it. The ſecond cauſe, which is truly the far greater, is this, becauſe in the diurnal motion of the Sun, equal parts of the *Æquator*, does not anſwer to equal parts of the *Zodiack*. Hence it followes, that if the natural dayes be not equal among themſelves, the hours muſt be unequal alſo: but this is not conſiderable.

By help of ſuch a Tub placed in a dark room, it is eaſie, when the Sun is under Eclipſe, to enumerat diſtinctly

ly the digits eclipsed. Likewise, if you take out the object Glass, and cover a hole in the window board with it, you shall see distinctly upon a white wall, the *species* and true representations of all objects without. And by comparing the quantity of the object without, with the quantity of it within, you may know the distance of it from the window, though it were many miles. For as the one quantity, is to the other, so is the distance between the Glass and the object on the wall, to the distance between the Glass and the object without.

It may be inquired whether or not, the *retrograde*, as well as the *diurnal motion* of any of the Planets, may be discerned, in *minuts* or *seconds*, by the help of a long *Telescope*? In answer to this, we must suppose the Planets only to have a *retrograde* motion, and consequently to move slowly from West to East, *Saturn* once in 29 years, or 30, to run about the *Zodiack*; *Jupiter* in 12, *Mars* in 2 years, the Sun in one year, *Venus* and *Mercury* in less time, and lastly the *Moon* in a moneth. Now I say, it is impossible by the longest Tub, that the greatest *Artist* can make, to discern the motion of the inferior Planets, far less the motion of the superior, either in *Minuts* or in *Seconds*, and that by reason of the great tardity, and slowness of the motion. Notwithstanding of this, I am induced to think, that the retrograde motion of the *Moon* might be discerned, at least in *Minuts*. For evincing of this, let us suppose which is true, that the *Sun* runs from East to West half a degree in two Minuts of time, seing in an hour he runs 15 degrees. Next, that the *Moon* goes about the *Zodiack* in 27 dayes and 7 hours, namely from that same point, to that point again, and consequently runs back every day 13 degrees and about

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10 Minuts. By this account, she must *retrograde* half a degree, and about 2 minuts of a degree every hour. The *Sun* then runs half a degree in two *Minuts*, and the *Moon* half a degree in 60 *Minuts*; therefore the *Moon* must be 30 times slower in her *retrograde* motion, than the *Sun* is in his diurnal motion. Let us suppose next, as I observed with a Tub 12 foot long, that the image of the *Sun* runs the eighth part of an inch every *second*, and consequently, seven inches and an half, in a *Minut*: then must the image of the Moon with that same *Telescope*, run the thirtieth part of seven inches and a half in a Minut, seing she runs 30 times slowlier; therefore in every *Minut* of time she must advance the fourth part of an inch, which will be very sensible. Though we grant, that the *Moon* hath no *retrograde* motion properly, yet by comparing the diurnal Motion of the *Moon*, that's slower, to the diurnal motion of the *Sun*, that's swifter, we shall really find the thing it self. Therefore in the time of a *Solar Eclipse*, this *retrograde* motion is conspicuous, which by an ordinary *Telescope* may be discerned in *Minuts*. Assoon then as the East side of the *Moon*, begins to enter upon the West side of the *Sun* (the greater the *Eclipse* be, it is the better) observe, and you will find the one image, which will be black, cover the other by degrees, that's splendid, and run in every minut of time, the fourth part of an inch of the *Suns* diameter, provided alwayes, that the *Sun* run the eighth part of an inch in a *second*.

OBSERVATION IV.

UPon *Tuesday* the 19. of *July* 1670, the following Experiment was made. In the middle Marches between *Scotland* and *England*, there is a long tract of Hills, that run from *Flowdon*, many miles South and South-west, amongst the which, the Mountain *Cheviot* is famous beyond, and conspicuous above all the rest for altitude, from whose top a man may discern with one turning of his eye, the whole Sea-coast from *New-castle* to *Berwick*, much of *Northumberland*, and very many Leagues into the great *German Ocean*: the whole *Mers* and *Teviotdale*, from the foot of *Tweed*, to very near the head of it: *Lauderdale*, and *Lammer-moor*, and *Pentland-hills* above *Edinburgh*. The North side of this Mountain is pretty steep, yet easie to climb, either with men or horse. The top is spacious, large and broad, and all covered with a *Flow-moss*, which runs very many miles South. When a man rides over it, it rises and falls. 'Tis easie to thrust a Lance over the head in it. The sides of this Hill abounds with excellent Well-springs, which are the original of several Torrents, amongst the which *Colledge-Water* is famous, upon which, not a mile from the foot of this Mountain is *White-hall*. The adjacent Hills are for the most part green, and excellent for the pasturage of Cattel. Not many years ago, the whole Valleys near the foot of *Cheviot*, were Forrests abounding with *Wild-Deer*.

Upon the highest part of this Mountain was erected the *Torricellian Experiment* for weighing of the Air, where we found the altitude of the *Mercurial Cylinder* 27 inches and an half. The Air was dry and clear, and no wind. In our Valley-Countreys, near to the Sea-Coast, in such

Weather,

Weather, we find the altitude 29 inches and an half. When this difference was found, care was taken to seal up closly with *Bee-wax*, mixed with *Turpentine*, the orifice of the Vessel, that contained the stagnant Mercury, and thorow which the end of the Pipe went down. This being done with as great exactness as could be, it was carried to the foot of the Mountain in a Frame of Wood, made on purpose, and there opening the mouth of the Vessel, we found the Mercury to rise an inch and a quarter higher than it was. The reason of this strange *Phenomenon* must be this, namely a greater Pressure of the Air at the foot of the Hill, than upon the top: even as there is a greater Pressure of Water in a surface 40 fathom deep, than in a surface 20 fathom deep. 'Tis not to be doubted, but if the root of the Mountain had been as low as the Sea Coast, or as the surface of *Tweed* at *Kelso*, the *Mercurial Cylinder* would have been higher. This way of observing, seems to be better than the common: for while the *Baroscope* is carried up and down the Hill, without stopping the orifice of the Vessel, that contains the stagnant Mercury, the *Cylinder* makes such reciprocations, by the agitation of a mans body, that sometimes abundance of Air is seen to ascend up thorow the Pipe, which in effect makes the *Cylinder* shorter than it ought to be. But if so be, the end of the Pipe be immerged among *Quick-silver*, contained in a Glass with a narrow orifice, so that it may be stopped compleatly, you will find no reciprocations at all. And to make all things the more sure, the Glass may be filled up either with *Mercury*, or with Water above the *Mercury*; by which means the *Cylinder* in the down-coming, or in the up-going shall remain immoveable. Besides the stopping of the orifice of the said Glass, you may have a wider Vessel,

ſel, that may receive the ſame Glaſs into it, and it being full of Water, may ſo cover the ſealed orifice, that there ſhall be no hazard of any Air coming in. Or this Experiment may be firſt tried at the root of the Hill, and having ſtopped compleatly the mouth of the Veſſel, the whole Engine may be carried up to the top, where you will find the *Mercury* ſubſide and fall down ſo much ; namely after the ſaid orifice is opened : for as the ſtopping of the orifice at the root of the Hill, is the cauſe, why that ſame degree of Preſſure remains in the ſtagnant Liquor ; ſo the opening of it upon the top of the Hill, is the cauſe why it becomes leſs.

This Experiment lets us ſee, that the Preſſure of the Air ſeems to be as the Preſſure of the Water, namely the further down the greater ; and the further up the leſs : and therefore, as by coming up to the top of the Water, there is no more Preſſure, ſo by coming up to the top of the Air, there is no more weight in it ; which in effect ſayes, that the Air hath a determinat hight,as the Water hath. From this Experiment we cannot learn the determinat hight of the Air, because the definit hight of the Mountain is not known. I know there are ſome, who think that the Air is indefinitly extended, as if forſooth, the Firmament of fixed Stars were the limits of it, but I ſuppoſe it is hard to make it out.

OBSERVATION V.

JUne 5. 1670. I obſerved the *Sun* within 3 *minuts* of ſetting, to have a perfect *oval figure*, the two ends lying level with the Horizon. His colour was not red as ordinarily, but bright and clear, as if he had been in the

Meridian: neither was the Sky red, but clear alſo. And by the help of the *Pendulum Clock*, I have obſerved his body to be longer in ſetting than it ought, by eight *minuts*, and ſometimes by *ten*; and his Diameter longer in going out of ſight than it ought, by two, and ſometimes by three *minuts*. The reaſon of theſe *Phenomena*, muſt be the *Refraction* unqueſtionably.

OBSERVATION VI.

UPon *Saturday* evening the 30 of *July* 1670, and the night following, till about two a Clock in the *Sabbath* morning, there fell out a conſiderable rain, with great thunder, and many lightnings. About *Sun-ſet*, the convocation of black clouds appeared firſt towards the *Horizon* in the South-weſt, with ſeveral lightnings; and the wind blowing from that point, carried the clouds and rain over *Mid* and *Eaſt-Lothian*, towards the *Firth* and *Sea-coaſt*. About 9 a clock, the whole Heavens almoſt were covered with dark clouds, yet the rain was not very great, neither were the *thunder claps* frequent, but every *fifth* or *ſixth ſecond* of time, a large and great lightning brake out. But before the *thunder crack* was heard, which happened every fourth or fifth *minut*, the lightning was ſo terrible for greatneſs, and brightneſs, that it might have bred aſtoniſhment. And becauſe the night was very dark, and the lightning very ſplendid, a man might have perceived houſes and corn-fields at a great diſtance. And if any had reſolved to catch it, in the breaking out, it did ſo dazle the eyes, that for half a *minut*, he was not able to ſee any thing about him.

Sometimes the lightning that went before the thunder, brake

brake forth from the clouds, like a long ſpout of fire, or rather like a long flame raiſed high, with a Smiths Bellows, but did not continue long in ſight. Such an one above the Firth was ſeen to ſpout downward upon the Sea. Sometimes there appeared from the one end of the cloud to the other, an *hiatus*, or wide opening, all full of fire, in form of a long furrow, or branch of a River, not ſtraight, but crooked. I ſuppoſe the breadth of it, in it ſelf, would have been twenty pace and more, and the length of it five or ſix hundred pace: the duration of it, would have been about a ſecond of time. Sometimes a man might have perceived the nether ſide of the cloud, before the crack came, all ſpeckled with ſtreams of fire, here and there, like the ſide of an Hill, where Moor-burn is, which brake forth into a lightning. But there was one, after which followed a terrible thunder crack, which far exceeded all the reſt, for quantity and ſplendor. It brake out from the cloud, being ſhot from North to South, in form of fire from a great *Cannon*, but in ſo great quantity, as if a Gun ten foot wide, with 500 pound weight of Powder in it, had been fired. And ſurely the lightning behoved to be far greater in it ſelf, ſeeing it appeared ſo great, at ſo great a diſtance. It did not evaniſh in an inſtant, like the fire of a Gun, but continued about a ſecond and an half; by reaſon (it ſeems) that it could not break out all at once. This did ſo dazle the ſight, that for half a minut almoſt, nothing was ſeen, but like a white miſt flying before the eyes. The whole Countrey about was ſeen diſtinctly.

All theſe great lightnings were ſeen a conſiderable time, before the crack was heard. Sometimes 30 *ſeconds* numbered by the *Pendulum Clock* interveened, namely when the thunder was at a diſtance, about 7 or 8 miles. Some-

times 15 or 16 only interveened. But when the thunder was just above our head, no moe passed, than 7 or 8, which seems to demonstrat, that these thick black clouds, out of which the thunder breaks, are not a *Scottish* mile from the earth, when they are directly above us.

'Tis observable, that in all lightnings, and thunderings, there is no smoke to be seen, which seems to evince, that the matter whereof they are generated, must be most pure, and subtil. Who knows, but this Countrey, that abounds with *Coal*, may occasion more thunder and lightnings, than other places, namely by sending up sulphurious exhalations to the middle region of the Air, wherewith the *Coal-mines* abound.

OBSERVATION VII.

THis is a method for finding out the true South and North Points, which are in effect very difficult to know. Take therefore four pieces of Timber, each one of them five foot long, and about six inches thick, squarewise. Sharpen their ends, and fix them so in the ground, that they may stand Perpendicular, and as near to South and North, by a *Magnetick Needle*, as may be. The place would be free of Trees, or of any such impediment, that it may have a free prospect of the Heavens. As for their distance one from another, let the two North-most, and the South-most be two foot asunder: let the two East-most, and two West-most, be but one foot, making as they stand, an *oblong quadrangle*. For keeping them equidistant above, as well as below, take four bars of Wood, about three inches broad, and one inch thick, and nail them round about upon the four sides, on each side one, so that

being

being nailed on *Horizontally*, they may make *right angles*, with the tops of the ſtandards above. There are then for diſtinctions cauſe, the North-bar, and the South-bar, that runs Eaſt and Weſt, and the Eaſt-bar, and the Weſt-bar, that runs South and North; There is here no difficulty in the thing it ſelf, but only in the fancy to conceive it. Beſides theſe four, there muſt be other four of the ſame form and faſhion, nailed on farder down about the middle of the four ſtandards. Take next ſome ſmall Braſs Wyre ſtrings, ſuch as are uſed in *Virginals*, and fix one from the middle of the South-bar, that's upmoſt, to the middle of the South-bar juſt under it. Fix it ſo, that it may be exactly Perpendicular, which may be done, with a great weight of Lead. Take a ſecond Wyre ſtring, and hang it plumb from the Weſt end of the North-bar, and another from the Eaſt end of the ſame Bar, I mean the Bar that's neareſt to the top. Theſe three ſtrings ſo fixed, will go near to make an *equilateral triangle*.

Now becauſe the device is for finding out the *Meridian* by the Stars in the night time, not by any indifferently, but by theſe that are neareſt to the *Pole*, therefore obſerve in *July* and *Auguſt*, when the *Guard-ſtars* in the evening begin to come down towards the Weſt, and keeping cloſs one eye, bring the other ſomewhat near to the South-moſt ſtring, and order your ſight ſo, that this ſtring, and the Weſt-moſt ſtring upon the North ſide, may catch the foremoſt *Guard-ſtar* in the down-coming, when it is furtheſt Weſt, and there fix it. When the ſame Star is turning up towards the Eaſt, catch it by the South-moſt ſtring, and the Eaſt-moſt ſtring on the North ſide, and your work is done, if ſo be, you divide exactly, between the Eaſt-moſt and Weſt-moſt, and there hang a fourth ſtring, which

with

with the ſtring upon the South-ſide, gives you the true South and North. For better underſtanding, note firſt, that, when the *Guard-ſtars* are coming down, or going up, the *Altitude* varies quickly, but the *Azimuth*, or motion from Eaſt to Weſt, will not vary ſometimes ſenſibly in two hours almoſt, which is a great advantage in this caſe. But when you find out the *Meridian* with a *Plain*, and a Perpendicular *Stilus*, by the ſhadow of the Sun, if it be not when he is about Eaſt and Weſt, the *Azimuth* alters more than the *Altitude*, which is a great diſadvantage. Now its certain, the ſlower the motion be from Eaſt to Weſt of any Star, it is the eaſier to obſerve, and it is the more ſure way. Note ſecondly, that ſpecial care muſt be had, to cauſe the ſtrings hang Perpendicular. Note thirdly, that before you begin your Obſervations, the South-moſt ſtring muſt be made immoveable, but the Eaſt-moſt, and Weſt-moſt, on the other ſide, muſt not be ſo, becauſe as the Stars in going about move from Eaſt to Weſt, ſo muſt the ſaid two ſtrings be left at liberty, to move a little hither and thither, till the Obſervations be ended. Note fourthly, that aſſoon as you perceive ſenſibly, the foremoſt *Guard-ſtar* to decline towards the Weſt, then you muſt begin to obſerve, which is nothing elſe, but to fix your eye ſo, that the South-moſt and Weſt-moſt ſtring, may cover the ſaid Star. And becauſe in coming down, it goes Weſt, therefore, let the Weſt-moſt ſtring move towards the left hand by degrees, following the Star to its utmoſt, till it be covered by them both. Follow the ſame method, in obſerving the ſame Star in going up towards the Eaſt. Note fifthly, that when you make the two ſtrings cover the Star, that which is neareſt to the eye, will appear tranſparent, and of a larger ſize, ſo that you may perceive diſtinctly

thorow

thorow it, not only the Star it self, but the other ſtring alſo, which is a great advantage. This is evident to any, who holds a bended ſilk thread between their eye and a Star in the night time; for when you direct your ſight to the Star, the ſtring appears like the ſmall ſtring of a *Virginal* when it trembles. Note ſixthly, that in obſerving in a dark night, you muſt have a *Cut-throat*, that by the light of the candle you may perceive the ſtrings. Some other things might be noted, but you will find them better by experience, than they can be expreſt here.

I named *July* and *Auguſt* in the evening for obſerving the *Guard-ſtars*, when they are Weſt-moſt, but there are ſeveral other ſeaſons, when this may be done as conveniently. They are Eaſt-moſt in the latter end of *October*, and beginning of *November* about 5 or 6 a clock in the morning. If a man were deſirous to make this obſervation quickly, I ſuppoſe he might in the end of *October*, find the ſaid ſtars Weſt-moſt in the evening, and Eaſt-moſt the next morning. Beſides the *Guard-ſtars*, a man may make uſe of the *Polar-ſtar*; for as it goes higher, and lower than the true *Pole*, by 2 degrees and 26 minuts, ſo it goes as much to the Eaſt, and as much to the Weſt, once in 24 hours. In the end of *July*, you will find the *Polar-ſtar* Eaſt-moſt, about 9 a clock at night, and in the end of *January* Weſt-moſt at 9 a clock. Note, that every month, the fixed ſtars come ſooner to the ſame place by two hours: therefore in the end of *Auguſt* the *Polar-ſtar* muſt be Weſt, at 7 a clock at night, and Eaſt at 7 a clock in the morning. When the *Meridian* is found out after this manner, there is no *Star* or *Planet* can paſs it, but you may know exactly when, be it never ſo high, or never ſo low. For there is nothing to be done, but to wait, till the South-moſt and North-

moſt

most string cover the body of the *Star*. If it be the Sun, hold up a white Paper, behind the two strings, and when their shadows do co-incide, and are united, then is his Center in the *Meridian*. If the Sun do not shine clear, as when he is under mist, or a thin cloud, you may exactly take him up in the *Meridian*, with the two strings. This Frame will serve as well, to know when any of the North Stars comes South, or North, and consequently when they are highest, and when they are lowest: for being fixed in an open place of the *Orchard*, there's no *Celestial Body* can pass the *Meridian*, either on the one side, or the other, but it may be catched, what ever the Altitude be, and that most easily.

OBSERVATION VIII.

THere hath been much inquiry made by some anent the reason, why the dead body of a man or beast, riseth from the ground of a Water, after it hath been there three or four days. But though many have endeavoured to solve the question, yet the difficulty remains; and in effect it cannot be answered, without the knowledge of the foregoing Doctrine, anent the nature of fluid Bodies. To find out the reason then of this *Phenomenon*, consider, that all Bodies, are either naturally heavier then Water, as Stone and Lead, or naturally lighter, as Wood and Timber. If they be heavier, they sink: if they be lighter, they swim. Now I say, a mans body immediatly after he is drowned, his belly being full of Water, must go to the ground, because in this case, it will be found *specifically* or *naturally* heavier then Water. That's to say, a mans body, will be heavier, than as much Water, as is the

the bulk of a mans body. For pleasing the fancy, imagine a Statue to be composed of Water, with all the true dimensions of the person that's dead, so that the one shall answer most exactly to all the dimensions of the other. In this case, if you counterpoise them in a Ballance, the real body, that's made up of flesh, blood, and bones, shall weigh down the other. But after this dead body hath lien a short time among the Water, it presently begins to swell, which is caused by the fermentation of the humors of the blood, which goeth before putrefaction, and after three or four dayes swells so great, that in effect, it becomes naturally lighter than Water, and therefore riseth. That is to say, take that body, that is now swelled, and as much bulk of Water, as will be the precise quantity of it, and having counterpoised them in a Ballance, you will find the Water heavier than the body.

OBSERVATION IX.

UPon *Thursday* the 25 of *August* 1670, the following Experiment was made in a new *Coal-sink*, on the West side of *Tranent*. When the *Coal-hewers* had digged down about 6 or 7 fathom, they were interrupted sometimes with *ill Air*: therefore to know the power and force of the *Damp*, we let down within the Bucket a *Dog*. When he had gone down about 4 fathom, or middle Sink, we found little or no alteration in him, save only that he opened his mouth, and had some difficulty in breathing, which we perceived evidently: for no sooner he was pulled up to the top, where the *good Air* was, but he left off his gaping. We let him down next to the bottom, where he tarried a pretty while, but no more change we found in

him than before. After this we let down a great quantity of *Whins*, well kindled with a bold flame, but they no sooner came to the middle of the *sink*, but the flame was in an instant extinguished: and no sooner was the Bucket pulled up, but they took fire again. This was 5 or 6 times tried, with the same succes. If we compare this Observation with the first, we will find, that all *Damps* are not of the same power and force; but that some are stronger, and kills men and beasts in an instant: and that others are less efficacious, and more feeble, and doth not so much hurt, and that men may hazard to go down into a *Sink*, where *ill Air* is, even though fire be sometimes extinguished. We see next, that these *Damps* doth not alwayes infect the whole Air of a *Coal-pit*, but only a certain quantity: for sometimes it is found in the bottom, sometimes in the middle. And we see lastly, that they are not alwayes of long continuance: for it is found, that though the Air be ill in the morning, yet it may be good ere night; and totally evanished ere the next day. We may add, as was noted in the first Observation, that these *Damps* depend much upon the scituation of the winds, seing in strong Southerly winds, they are frequently in these places.

OBSERVATION X.

OF these many excellent devices, that have been found out of late, the *Air-pump* is one, first invented in *Germany*, and afterwards much perfected in *England* by that Honourable Person Mr *Boyl*, who for his pains, and industry in making Experiments therewith, deserves the thanks of all learned persons. Several trials hath been made of late by it, some whereof, are as follows. I took a slender

Glass-

Glaſs-tub about 40 inches long, cloſs above, and open below, and filled it with VVater. I next inverted it, and ſet the orifice of it, juſt upon the mouth of the Braſs-pipe, that bends upward thorow the board, whereon the *Receiver* uſeth to ſtand, and cemented them together. At the firſt exſuction, the whole VVater in the Pipe fell down, and ran thorow the *Braſs-conduit* to the Pump. Having for a ſhort while ſtopped the paſſage, and thruſt down the *Sucker*, I next opened it again, and the *Pump* being full of VVater, it was driven with a conſiderable force up thorow the Pipe; yet was it not compleatly fill'd as before, by reaſon of ſome Air, that I ſaw in the top. After this was done, with pleaſure five or ſix times, I opened the *Stop-cock* more quickly, than I had uſed, but the VVater, by this means, was ſo furiouſly driven up thorow the Tub, that in effect, it broke the end of it, that was *Hermetically ſealed*; and the piece that flew off, did hit the ſeiling ſo ſmartly, that it rebounded a very far way. From this we ſee the reaſon, why VVater falls not down from Veſſels that have narrow necks, though they be inverted, becauſe it's kept in by the force and power of the environing Air. 'Tis obſervable, that though this Pipe had been 30 foot high, yet the whole VVater in it would have ſubſided, and fallen down, with one exſuction.

The next trial was with the help of a ſmall *Receiver*, which in effect was a real *Cupping-glaſs*. This had a hole made in the bottom of it, and was cemented to the *Braſs-plate*, and the mouth of it looking upward, had a lid for covering of it. I took next the lately mentioned Glaſs-pipe, and filled it with good *Brandy*, and having drowned the end of it among ſtagnant *Brandy*, I ſet the Veſſel wherein it was within the *Receiver*, the Pipe coming up thorow

the lid, and having cemented it closly, I made the first exsuction, and found no descent of the Liquor from the top of the Tub. At the second, it fell down about an inch. At the third, it fell down four or five. But here appeared a great multitude of small Bubbles of Air, like broken VVater, near the top of the Pipe within. And besides this *Phenomenon*, there ascended from the stagnant Liquor up thorow the Pipe, an infinit number of small Bubbles, no bigger than Pin-heads, for a very large time. VVith a fourth exsuction, it fell down within two or three inches of the *stagnant Brandy*. And thinking to make the one level with the other, I made a fifth; but here appeared a strang effect, namely, not only the whole *Brandy* in the Pipe subsided, and was mingled with the *stagnant Brandy*, but at this exsuction, there came a great quantity of Air from the mouth of the Pipe, and rose up thorow the *stagnant Liquor* in Bubbles. Having made another exsuction, there came yet more Air out, and so copiously, that I thought there had been some leak in the Tub, through which the outward Air had entered; but knowing the contrary, I continued Pumping a very long time, till I found less and less come out, and at length, after near 30 exsuctions it ceased. This Air to appearance, was so much as might have filled twenty Tubs, every one of them as large, as the Tub it came out of. And surely all of it came out from among the small quantity of *Brandy* that filled the Pipe, and that environed the mouth of it, I mean the *stagnant Brandy*, both which would not have been eight spoonful. After this I opened the *Stop-cock* leasurely to let in the Air to the *Receiver*; then did the *Brandy* climb up the Pipe slowly, till it came near to the top, and there made some little halt, by reason of half an inch of Air that appeared

peared there. But more and more Air coming into the *Receiver*, that half inch in the top of the Pipe, did ſo diminiſh, that it appeared no bigger than the point of a Pin, and was ſcarcely diſcernable to the eyes. What a ſtrange and wonderful faculty of dilatation and contraction muſt be in the Air, ſeing that which preſently had filled the whole Tub, that was 40 inches long; and the ſixth part of an inch wide, was contracted to as little room, as the point of a Needle. And by making ſome new exſuctions, that ſmall *Atome* of Air did ſo dilate it ſelf again, that it filled the ſame Tub, and not only that, but, as formerly, it bubbled out from the mouth of the Pipe ſeveral times.

'Tis to be obſerved, that though at the firſt falling down of the *Brandy*, it appeared like broken Water, near the top of the Pipe within, yet no ſuch thing was ſeen the ſecond time it fell down; the reaſon is, becauſe by the firſt exſuctions, it was well exhauſted of its *aërial particles*. Once or twice I found, after the *Brandy* within the Pipe was well freed of Air, that no exſuctions could make it move from the top of the Tub; and obſerved a round Bubble of Air to march up, which when once it came to the top, did ſeparate the one from the other. If this hold good, it ſeems to prove, that neither Mercury, nor any other Liquor would fall down in Pipes, unleſs there were Air lurking amongſt the parts to fill up the deſerted ſpace.

From this Experiment we learn, that no perſon can well apprehend or conceive, how far, and to what bounds the ſmalleſt part of Air is able to expand it ſelf. And it proves evidently, that when the *Receiver* is as much emptied as it can be, by the Art of man, yet it is full of Air compleatly.

The

The third trial was after this manner: I ſet within the *Receiver* a little Glaſs half full of *Brandy*, and the lid being cemented on, I began to pump, but there appeared no alteration at the firſt exſuction. At the ſecond, I perceived a great company of very ſmall Bubbles, that for a long time aſcended from the body of it, and came to the ſurface. At the third, they were ſo frequent, and great, that the *Brandy* appeared to ſeeth and boil, and by reaſon of the great ebullitions, much of it ran over the lips of the Glaſs, and fell into the bottom of the *Receiver*. This boiling continued for the ſpace of 7 or 8 exſuctions, and by proceſs of time, the Bubbles grew fewer and fewer, and when about 30 or 40 exſuctions were made, no more appeared. With this ſame ſort of *Brandy*, I filled the fore-named Pipe, and ſet it within the *Receiver*, the mouth of the Tub being guarded with the ſame ſort of Liquor. When it began to ſubſide, there appeared no Bubbles near the top as before: the rearon ſeems to be, becauſe the *Brandy* was well exhauſted from its *aërial particles*. For a fourth trial, I filled the ſame Tub with Ale, that was only 5 or 6 dayes old, and drowning the end of it among ſtagnant Ale of the ſame kind, I began to Pump, and found, that aſſoon as the Liquor began to ſubſide, from the top of the Pipe, the whole Ale within the Pipe, almoſt turned into Air, and Froth, and ſo many large Bubbles came up from the ſtagnant Liquor, that I thought the whole was converted into Air. It was moſt pleaſant to behold their ſeveral forms and ſhapes, their order and motion. This ſame Tub being filled with *ſweet milk*, I found very few Bubbles in it, when by the exſuctions, it began to ſubſide. I likewiſe took a little Glaſs-viol, and fill'd the half of it full with common Ale, and ſet it within the *Receiver*. At the firſt exſuction,

Bubbles

Bubbles of Air began to riſe out of it. At the ſecond and third, they did ſo multiply, that they fill'd the other half of the Glaſs, and ran over, as a Pot doth when it boileth. And before I could exhauſt all the Air out of it, moe than 20 exſuctions paſſed.

For a fifth trial, I filled the often mentioned Pipe with Fountain-water, and when it began to ſubſide by Pumping, I found it leave much Air behind it. But all the exſuctions I made, could not make the Water of the Pipe go ſo low, as the ſtagnant Water, by which impediment, I could Pump no Air out of the Pipe, as I did, while I made uſe of *Brandy*. This tells us, that either there is not ſo much Air lurking among *Water*, as among *Brandy*, or that the Air among this, hath a more expanſive faculty in it, than the Air that lurks among *Water*. If any think, that it is not true and real Air, which comes from the *Brandy*, but rather the *Spirits* of it, which evaporats. I anſwer, if a man taſt this *Brandy* that's exhauſted of its *aërial particles*, he will find it as ſtrong, as before, which could not be, if the *Spirits* were gone,

For a ſixth trial, I took a *Frog* and incloſed her within the *Receiver*. But all the exſuctions I was able to make, could not ſo much as trouble her. Only, when the *Receiver* was exhauſted, I perceived her ſides to ſwell very big, and when the *Stop-cock* was turned, to let in the Air again, her ſides clapped cloſs together. I obſerved likewiſe, when the Air was pretty well Pumped out, that the *Frog* had no reſpirations, or if there were any, they were very inſenſible. The next day, after ſhe had been priſoner in the *Receiver* 24 hours, I began again to Pump, and after ſeveral exſuctions, her ſides ſwell'd pretty great, and I perceived her open her mouth wide, and ſomewhat like a

Bag endeavouring to come out, which surely hath been some of her noble parts, striving to dilate themselves, the body being freed of all Pressure from the ambient Air.

OBSERVATION XI.

TAke a slender chord, about 4 or 5 yards in length, and fasten the middle of it to the seiling of a Room with a nail, so that the two ends of it may hang down equally. Take next a piece of Wood, two or three foot long, two inches broad, and one inch thick, and boring an hole in each end of it, put through the two ends of the chord, and fasten them with knots; but so, that the piece of Wood may ly Horizontal, and be in a manner a *Pendulum* to swing from the one end of the Chamber to the other. Take next a Bullet of Lead or Iron, about 20 or 24 ounces, and lay it upon the said piece of Wood: but because it cannot well ly, without falling off, therefore nail upon the ends, and the sides of the Timber, four pieces of Sticks, on each end one, and on each side one, as *Ledgets*, for keeping the Bullet from falling off. All things being thus ordered, draw up the piece of Wood towards the one side of the Room, by which means losing its horizontal position, it will ly declining-wise, like the roof of an house. In this position, lay the Iron Bullet in the upmost end of it, and then let them both pass from your fingers, the one end of the Wood going foremost, and you will find it swing towards the other side of the house, and return again, as a *Pendulum*. This motion, if the Wood be well guided in its vibrations, will last perpetually, because in its moving down, the Bullet is hurled from the one end of the Wood, to the other, and hits it so smartly, that it begets in it, an

an impulſe, whereby it is carried farder up, than it would be, without it. By this means, the *vibrations* get not liberty to diminiſh, but all of them are kept of the ſame length. In the ſecond vibration, the ſame Bullet is hurled back again to the other end, and hiting it with all its weight, creats a ſecond impulſe, wherewith the Wood is carried, as far up as the point it was firſt demitted from.

Though this may ſeem a pretty device to pleaſe the fancy, that's many times deceived, while things are preſented to it, by way of ſpeculation, yet upon tryal and experience, there will be found, an unſpeakeable difficulty: and it's ſuch an one, that a man would not readily think upon. I ſaid, that when the Wood was let go, and was in paſſing down, the Bullet in it, would hurl down, and hit the oppſite end, and beget an impulſe; but there is no ſuch thing, for verily, though the Bullet be laid upon a very declining plain Board, whereupon no man could imagine a round body could ly, yet all the time the Board is in ſwinging, from the one ſide of the Chamber, to the other, and conſequently, ſometimes under an horizontal, and ſomtimes under an declining poſition, the Bullet lies dead in the place, where you firſt placed it. This Obſervation is not ſo much for a perpetual motion, as for finding out the reaſon of this pretty *Phenomenon*, namely, what's the cauſe, why the Bullet, that cannot ly upon a reclining Board, while it's without motion, ſhall now ly upon it, while it's under motion? What is more difficult, and nice, to ly upon any thing, that declines from a levell, than *Quick-ſilver*; yet lay never ſo much of it upon this Board, while it is ſwinging, it ſhall ly dead, and without motion. But no ſooner you ſtop the motion of the wood,

but assoon, the Bullet, or the *Quick-silver*, is hurled, either this way, or that way.

OBSERVATON XII.

I Find it mentioned by some learned persons, that when a Ship is under Sail, if a stone be demitted from the top of the Mast, it will move down in a line parallel with it, and fall at the root. Some might think, it ought not to fall directly above the place it hang over, but rather some distance behind, seing the Ship hath advanced so much bounds, in the time, wherein the stone is coming down. Likewise, while a Ship is under Sail, let a man throw up a stone never so high, and never so perpendicular, as to his apprehension, yet it will fall down directly upon his head again, notwithstanding that the Ship hath run (perhaps) her own length in the time, while the stone was ascending and descending. This experiment I find to hold true, which may be easily tryed, especially when a man is carried in a Boat upon smooth Water, drawn by a horse, as is done in some places abroad. Let him therefore throw up a little Stone, or any heavy Body, and he will find it descend just upon his head, notwithstanding that the Horse that draggs the Boat, be under a gallop, and by this means hath advanced ten or twelve paces in the time. Or while the Boat is thus running, let a man throw a stone towards the brink of the VVater; in this case he shall not hit the place he aimed at, but some other place more forward. This lets us see, that when a Gun is fired in a Ship under Sail, the Bullet cannot hit the place it was directed to. Neither can a man riding with a full Career, and shooting a Pistol, hit the person he aims at, but must surely miss him,

him, notwithſtanding, that though in the very inſtant of time wherein he fires, the mouth of the Piſtol was moſt juſtly directed. For remedy whereof, allowance muſt be granted in the aiming at the mark.

VVhile a man throws up a ſtone in a Ship under Sail, it muſt receive two diſtinct impulſes, one from the hand, whereby it is carried upward, the other from the Ship, whereby it is carried forward. By this means, the ſtone in going up, and coming down, cannot deſcribe a perpendicular, but a crooked Line, either a *Parabola*, or a Line very like unto it. Neither can it deſcribe a perpendicular Line, in coming down from the top of the Maſt, though in appearance it ſeem to do ſo, but a crooked one, which in effect muſt be the half of that, which it deſcribes in going up, and coming down. For this ſame cauſe, a ſtone thrown *horizontally*, or towards the brink of the VVater, muſt deſcribe a crooked Line alſo. And a *Piſtol Bullet* ſhot, while a man is riding at a full Carreer, muſt deſcribe a Line of the ſame kind. Note, that a man walking from the *Stern* of a Ship to the *Head*, walks a longer way, than in walking from the *Head* to the *Stern*. Secondly, a man may walk from the *Head* to the *Stern*, and yet not change his place. 'Tis obſervable, that a man *under board*, will not perceive whether the Ship be ſailing, or not, and cannot know when her *Head* goes about. And it is ſtrange, that when a man is incloſed in a *Hogs-head*, though he have light with him, yet let him be never ſo oft whirled about, he ſhall not know, whether he be going about, or not.

OBSERVATION XIII.

I Found in a *Philoſophical tranſaction* lately Printed, that *Decemb.* 13. 1669, one *Doctor Beal* found the Mercury in the *Baroſcope*, never to be ſo high, as it was then. That ſame very day, I found the hight of it 29 inches, and nine ten parts, which I never obſerved before. And though the day here was dark, and the Heavens covered with Clouds, yet no rain for many dayes followed, but much dryneſs, and fair weather. On *Saturday* night, *March* 26, 1670, I found the altitude no more than 27, and nine ten parts. This night was exceeding windy, with a great rain. On *February* 1. 1671. I found the altitude 30 inches, and the Heavens moſt clear. But in the moſt part of *May* following, I have found the hight but 27 inches, and five ten parts, in which time there was abundance of rain.

OBSERVATION XIV.

NOvember 7. 1670. I made exact trial, with the *Magnetick Needle* for knowing the variation, and I found it vary from the *North*, three degrees and a half, towards the Weſt. *Hevelius* writes from *Dantzick* to the *Royal Society* at *London*, *July* 5. 1670, that it varies with him ſeven degrees twenty minuts, weſt.

OBSERVATION XV.

DEcember. 17. 1669, I obſerved with a large *Quadrant*, half 9 a clock at night, the formoſt *Guard-ſtar*, when it was in the *Meridian*, and loweſt, to have 41 degrees

grees 22 minuts of altitude. And on *January* 7. 1670 at 7 a clock in the morning, I found it, when it was in the *Meridian*, and higheſt, to have 70 degrees, 27 minuts. Hence I conclude the *elevation of the Pole* here to be 55 degrees, 54 minuts, 30 ſeconds: and conſequently as much at *Edinburgh*; becauſe both the places are upon one and the ſame Parallel.

OBSERVATION XVI.

FOr finding the true *Meridian*, follow this method. In ſome convenient place fix two Wyre ſtrings with weights at them, that they may hang perpendicular. Then in the night time,obſerve,when the *fourth ſtar of the Plough* begins to come near to the loweſt part of the *Meridian*, at which time you will find the *Polar ſtar* higheſt. Then, ſo order the two ſtrings, by moving them hither, and thither, till both of them cover both the ſaid *Stars*, then ſhall they in that poſition give you the true *South* and *North*. This obſervation is the product of the ſevenrh.

OBSERVATION XVII.

THere fell out in *Mid* and *Eaſt-Lothian*, on *Thurſday May* 11, 1671, in the afternoon, a conſiderable ſhour of *hail*, with thunder and rain. It came from the South-weſt, with a great blaſt of wind, and ran alongs from *Picts-land-hills* North-eaſt, towards the Sea-coaſt. The *hail* were big in ſeveral places,as *Muſquet Ball*, and many of them rather *oval* than *round*. Some perſons ſuffered great loſs of their *young Peaſe*; others of their *Glaſs Windows*. Eight or ten days before, there was a conſiderable heat,

and

and dry VVeather. For 20 dayes after, cold Easterly winds, with rain every day, but especially, in the end of the Moneth, extraordinary rain and mist. This is so much the more to be observed, because in this Countrey, seldom such extraordinary *hail* falls out. This year the *Agues* and *Trembling Fevers* have been most frequent, and to many deadly.

OBSERVATION XVIII.

I Did hear lately of a curious Experiment in *Germany*, made by a Person of note, which I shall briefly in this Observation, let the *Reader* understand. And though I have heard since, that it is now published in Print, yet I hope it will not be impertinent to mention it here, especially for their cause, who cannot conveniently come to the knowledge of such things. And for this reason also, that I may explicat the *Phenomena* thereof, from the foregoing doctrine, and demonstrat particularly the true cause of that admirable effect, that's seen in it, which I desiderat in the publisher. The Auctor then takes two *Vessels* of *Brass*, each one of them in form of half a sphere, of a pretty large size. Nothing can more fitly represent them for form and quantity, than two *Bee-skeps*. Only, each of them, hath a strong *Ring* of Brass upon the *Center* without: and they are so contrived by the *Artist*, that their orifices agree most exactly, so that when they are united, they represent an intire Sphere almost. In one of the sides, there's a hole, and a *Brass Spigot* in it, through which the whole *Air* within, is exsucted, and drawn out, namely by the help of the *Air-pump*. And, when by several exsuctions the *Vessels* are made empty, the *Stop-cock* is turned

about,

about, by which means, no *Air* can come in. And, they remaining empty, are taken from the *Pump*, and do cleave so fast together, that though a number of *lusty fellows*, 12 on each side, do pull vigorously, by help of ropes fastned to the *Rings*, yet are they not able to pull them asunder. And because this will not do it, he yokes in 12 *Coach Horses*, six on every side, yet are they not sufficient, though they pull contrariwise to other, to make a separation. But to let the *Spectators* see, that they may be pulled asunder, he yokes in 9 or 10 on every side, and then after much whipping, and sweating, they pull the one from the other.

The cause of this admirable effect, is not the fear of *vacuity*, as some do fancy, for if that were, all the *Horses* in *Germany* would not pull them asunder, no not the strength of *Angels*. It must then be some extrinsick weight and force, that keeps them together, which can be nothing else, but the weight of the *invironing Air*. Because, no sooner a force is applied, that's more powerful, than the weight of the *Air*, but assoon they come asunder. And so neither six men, nor six horses on each side are able to do it: but nine or ten on each side makes a separation. For understanding the true cause of this *Phenomenon*, we must consider that the *Vessels* are 18 inches in *diameter*. If this be, then according to the last Experiment, there are two Pillars of *Air*, each one of them as heavy as a Pillar of *Mercury* 18 inches thick, and 29 inches long, by which they are united. Or, each Pillar of *Air*, is as heavy, as a Pillar of *Water* 34 foot high, and 18 inches in *diameter*. For finding the weight of it in pounds, and consequently, the weight of each Pillar of *Air*, by which the two *Vessels* are united, follow this method, First, multiply 9 the semi-diameter

diameter of the *Pillar*, by 54 the circumference, and this gives you 486, the half whereof is the bounds of the *Area*, namely 243. And becaufe 34 foot contains 408 inches, I multiply 408 by 243, the product whereof is 99144; fo many fquare inches are in a Pillar of Water 34 foot high, and 18 inches thick. Now feing there are 1728 inches in a *cubical foot*, I divide the number 99144, by this number, and I find 57 fquare foot of Water, and more. And becaufe every fquare foot weighs 56 pound *Trois*, I multiply 56 by the number 57, and the product is 3192 pound, which is the juft weight of a Pillar of *Water* 34 foot high, and 18 inches in diameter, and which is the juft weight alfo of each Pillar of *Air*, by which the two *Veffels* are kept together, which will be more weight than *feven Hogsheads full of Water*. This is eafily known; for feing a quart of our meafure weighs feven pound, (or to fpeak ftrictly, fix pound fourteen ounces, feing the *Standard-jug* of *Striviling* contains three pound feven ounces of Water) a gallon muft weigh 28 pound: but 16 times 28, is 448. A *Puncheon* then full of Water, weighs 448 pound. If then you divide 3192 by 448, you will find more than 7. The 9 horfes then upon this fide have 3192 pound weight to draw, or 199 ftone, or the weight of *feven Hogs-heads full of Water*. The other 9 horfes upon the other fide, have as much to pull. 'Tis no wonder then to fee fo much difficulty and pains to make a feparation. It is obferved, that before the *Air* be exfucted and drawn out of the two *Veffels*, one man is able to pull them afunder with his hands only. Nay, which is more, if he but blow into them, as a man doth into a Bladder, he will feparat them. The reafon is, becaufe the *Air* within, is of as great force, as the *Air* without. 'Tis obfervable next, that the larger the *Veffels* be

in

in *diameter*, the more ſtrength is required to pull the one from the other. Upon ſuppoſition then, they were 4 foot wide, I verily believe 30 yoke of oxen, upon every ſide, would hardly diſjoyn them; becauſe the weight of each Pillar of Air, would be no leſs, than 22844 pound, which would take 63 ſtrong horſes to overcome the force of it. To pull the one *Veſſel* therefore from the other, there muſt be 126 horſes, that is, 63 on every ſide.

OBSERVATION XIX.

THough this Obſervation may ſeem uſeleſs, becauſe the Propoſals, that are mentioned in it, cannot be made out, and brought to paſs, the *Author* having died, before he had encouragment to proſecute them: yet for theſe following reaſons, I have adventured to inſert it here. Firſt, that others, may either be minded to find out (if poſſible) his inventions, or ſet a work to find out ſomethings, that may be as uſeful. Next, becauſe, he was one of this ſame *Nation*, and a great *Maſter* of the *Mathematicks*, not only in the *Speculative*, but in the *Practical* part chiefly, and admirable for invention. And for this cauſe principally I have preſumed to mention his deſigns, and propoſals, which were found among his *Notes*, after his death, which are here inſert, as they were written with his own hand, and offered to the publick, not only at home, but abroad to ſtrangers. There have been men in all ages famous, for ſome one Art and Science beyond others, as *Apelles* for Painting, *Hippocrates* for Medicine, *Demoſthenes* for Oratry, but who have been more famous in their time than ſome perſons for there profound knowledge in *Aſtronomy*, *Geometry*, and the other parts of the *Mathematicks*. What

an admirable person was *Archimedes* for his divine knowledge, both in the *Speculative*, and *Practical* part. Yet, it was not his speculations simply, though excellent, that did so much commend him, as his *Inventions*, and admirable *Engines* for peace and war, as is clear from the *Romane Histories*, and others. I confess the Students of these Arts, are not so much in request now, at least amongst some, and that knowledge is not so much esteemed; and the reason may be; because some who profess themselves *great Masters*, study nothing but the pure speculations, which sometimes are to small purpose, others before knowing the same, unless for perfecting of the mind, and giving to a man some private satisfaction. But such things will never commend a man so much as the practical part, and new Invention will do. 'Tis surely a small business for one to do nothing, but to nibble at some petty Demonstration. But when such speculations are joyned with invention and practice, for the profit, and use of men, among whom they live, then are they far more to be commended. And if this be not, such knowledge is of small advantage to themselves or others. Many of the Ancient, and late Astronomers have been, and are famous for practice, as witness the indefatigable pains they have been at in making their Observations. What hath so highly commended *Merchiston* over all *Europe*, as his inventions, especially his *Logarithmes*? And if all be true, that's reported (which I am apt to believe) he might have been more renowned, for his many excellent *Engines*, which though useful, yet because hurtful to mankind, he buried with himself. I am confident, if the Author of these proposals had had time to have prosecuted them, he would have been celebrated in the Catalogue of the most famous *Mathematicians* of his time. But leaving this, I

shall

ſhall give you them in his own words: but firſt his Apology.

These bold propoſals will need perhaps an apology to ſuch, to whom the cauſes, and circumſtances are unknown. Let it ſuffice, that the Propoſer finding himſelf between two extreams, either to leave unproſecuted this affair, for fear of being miſtaken by ſome, as impudent, or to commit himſelf openly to the charitable judgement of others, who will ſuſpend their cenſure, till they have ſeen what his endeavours will produce. He hath rather choſen this laſt, eſpecially conſidering, that his ſilence could not anſwer to his duty, which he owes to his Countreys ſervice, ſeing the following Engines may be ſo uſeful to it. A deduction of the fabrick, cauſes, and occaſions of theſe *new Engines*, that ſet the Inventer a-work, would take a long time to diſcourſe upon. This Paper therefore is only deſtined for a ſhort information of their uſe, the reſt, which could not here be inſert without impertinency, may be ſupplied afterwards (if need be) either by a diſcourſe, or by a particular demonſtration. The Propoſer then is of opinion, (if ſelf-love of his own Inventions do not blind his Judgement) that theſe *paradoxes* may be truly affirmed.

That if it ſhall pleaſe His Majeſty to arm with theſe new Arms, and Engines, 5000 Foot, or fewer, this ſmall number ſhall be Maſters of the Fields in *France*, *Germany*, *Spain*, or where elſe it ſhall pleaſe His Majeſty, however encountered by the moſt powerful Army of Horſe or Foot, armed with ordinary Arms, of Piſtol, Carabine, Pike, Muſquet, which Europe can bring to the Fields.

The cauſe of this admirable effect, is in the quality of theſe new Arms, by which, the whole Horſemen and Footmen of the enemy are rendred uſeleſs, and unſervicable; neither

neither can they do any offence to these, who are so armed.

The *Musquetteers*, who can only serve against these *Machins*, shall be put to such disadvantage, as it is impossible they can stand, the least time, in the common way of service with the *Musquet*, it not being able to make one shot for twenty, which shall be made from these new Engines.

These *new Arms*, have this advantage likewise, that these who are so armed, can by no force of Horse or Foot be broken, or put to disorder. The Souldiers are also by them put to a necessity of keeping together, and fighting, and by them, they are so *Baricado'd*, and strongly defended, that if they leave them not, they cannot be exposed to danger. This contributes much to good Discipline, when the Souldiers shall by necessity be tied to his duty, and fear, which otherwise makes him run away, shall here for his safety make him stand.

These *new Arms* are useful, as well in Marching, as in Combating, for with them, we may march securely two in front, through the straitest passages, and be able to force with them any advantage a strait passage can give to an enemy. Besides, for a long hasty march, where Victuals cannot be well carried, the Souldiers are able with these *Arms* to carry their own provision for eight dayes, with more facility, then they can now carry one dayes provision.

To lodge in the open fields, these *Arms* shall need no Intrenching, for they sufficiently both Arm and *Baricade* the Souldiers.

And as they are useful in Service, so are they a great deal cheaper than the ordinary *Arms*. For although with 5 thousand men so armed, the service of 100000 armed with common Arms may be done, yet the whole price of

them

them will not amount to that which will be required for arming 20500 *Corraſſiers*, as may be particularly deduced, from the particular prices of the Arms, and Engines fitted for the ſervice of 5000 men. The Propoſer doth offer to ſhew, that theſe Arms will not ſurmount 40000 pound *Sterling*. The *Artillery* will amount to 4500, and the payments of this number of men ſo armed, yearly to 70000 pound. Yet all theſe are taken in ſo large a latitude of reckoning, as the ſum of *Arms*, *Artillery*, and payments, will not be much above 130000 pound *Sterling*.

The Arms from which this effect is promiſed, are *new Engines*, with which one man is able to do the ſervice of a great many *Muſquetteers*. And thoſe are of two ſorts, either to be uſed upon a ſmall Wagon for Footmen, or on a greater for a Horſe, with either of which, one hand is able to make the fire of 100 *Muſquetteers*, and ſo much better, by how much it is more regularly, and fitly done for execution and offence. The new Cannon ſhall have the like advantage above the old, both for eaſie carriage, being lighter, and for greater execution, ſhooting ſix, nine, or twelve Bullets for one. Theſe Arms give not only this advantage at Land in the field, but alſo in Ships, and places of defence.

Theſe nine following propoſitions he likewiſe offered to make good,

Firſt, With one ſhot of *Cannon*, to do the execution of five ſhot of the ſame *Cannon*, in the common way of Battery.

Secondly, to diſable any Ship or Galley with one ſhot of *Cannon*.

Thirdly, to fire any combuſtible matter with the ſhot of a *Cannon*.

Fourthly,

Fourthly, to make an *Machin* or *Engine* for transporting an Army, which may be carried without the incommodity thereof.

Fifthly, to make a flotting *Fortress* for defence of Rivers, and prohibition of Passages.

Sixthly, to make a *Mortar* that hath a *directory Stell* upon the Carriage.

Seventhly, to make *Petards* of divers forms, that shall be able to do twice as much execution, as those that contain as much Powder.

Eighthly, to make small *Petards* of great effect.

Lastly, to make *Bridges*, and *Scaling Ladders* of easie Carriage.

OBSERVATION XX.

THese Observations being *Miscellany*, require not a formal connexion between themselves, and therefore 'tis no matter what method I keep in setting them down. And though this may seem not so pertinent, as others, yet because the design of it is only *Philosophical*, and for advancing the *Historical* part of Learning in order to *Spirits*, upon which the *Scientifical* part doth so much depend, I have presumed to insert it here, considering also that there are some, who have adventured to deny their existence. and being; which from such a History as this, may be more than probably evicted. I find likewise, that several Writers have remarked such strange accidents, and have transmitted them to posterity, which may serve for good use. The subject-matter then of this Observation, is a true and short account of a remarkable trial, wherewith the Family of one *Gilbert Compbel*, by Profession a Weaver

ver in the old Paroch of *Glenluce* in *Galloway*, was exercised. Though the matter be well known to several persons at that time, and since too; yet there are others, eighteen years interveening, to whom (perhaps) such a relation will not be unacceptable, who have either not as yet heard of it, or at least, have not gotten the true informarion, which is here set down, as it was Written, at the desire of a special Friend, by *Gilbert Campbel*'s own Son, who knew exactly the matter, and all the circumstances, whose words are as follows.

It happened in *October* 1654, that after one *Alexander Agnew*, a bold and sturdy Beggar, who afterwards was hanged at *Dumfreis* for blasphemy, had threatned hurt to the Family, because he had not gotten such an alms as he required: the said *Gilbert* was oftentimes hindered in the exercise of his Calling, all his Working-Instruments being some of them broken, some of them cutted, and yet could not know by what means this hurt was done; which piece of trouble did continue, till about the middle of *November*, at which time the Devil came with new and extraordinary assaults, by throwing of Stones in at Doors and Windows, and down thorow the Chimney-head, which were of great quantity, and thrown with great force, yet by *Gods* good providence, there was not one person of the Family hurt, or suffered dammage thereby. This piece of new and sore trouble, did necessitat Mr. *Campbel* to reveal that to the *Minister* of the Paroch, and to some other Neighbours and Friends, which hitherto he had endured secretly. Yet notwithstanding of this, his trouble was enlarged; for not long after, he found oftentimes his Warp and Threeds cut, as with a pair of Sizzers, and the *Reed* broken: and not only this, but their apparel cut after

ter the ſame manner, even while they were wearing them, their Coats, Bonnets, Hoſe, Shooes, but could not diſcern how, or by what mean. Only it pleaſed *God* to preſerve their perſons, that the leaſt harm was not done. Yet, in the night time, they wanted liberty to ſleep, ſomething coming, and pulling their Bed-cloaths and Linnings off them, and leaving their bodies naked. Next, their Cheſts, and Trunks were opened, and all things in them ſtrawed here and there. Likewiſe, the parts of the Working Inſtruments, that had eſcaped, were carried away, and hid in holes and bores of the houſe, where hardly they could be found again. Nay, what-ever piece of Cloath, or Houſhold-ſtuff, was in any part of the houſe, it was carried away, and ſo cut and abuſed, that the Good-man was neceſſitated with all haſte and ſpeed, to remove, and to tranſport the reſt to a Neighbours houſe, and he himſelf compelled to quite the exerciſe of his Calling, whereby only he maintained his Family. Yet, he reſolved to remain in the houſe for a ſeaſon. During which time, ſome perſons about, not very judicious, counſelled him to ſend his children out of the Family, here and there, to try whom the trouble did moſt follow, aſſuring him, that this trouble was not againſt all the Family, but againſt ſome one perſon, or other in it, whom he too willingly obeyed. Yet, for the ſpace of four or five dayes after, there were no remarkable aſſaults, as before. The Miniſter hearing thereof, ſhewed him the evil of ſuch a courſe, and aſſured him, that if he repented not, and called back his children, he might not expect that his trouble would end in a right way. The children that were nigh by, being called home, no trouble followed, till one of his ſons, called *Thomas*, that was farreſt off, came home. Then did the Devil begin afreſh;

fresh; for upon the *Lords Day* following, in the afternoon, the house was set on fire, but by his providence, and the help of some people, going home from Sermon, the fire was extinguished, and the house saved, not much loss being done. And the *Monday* after, being spent in privat Prayer and Fasting, the house was again set on fire upon the *Tuesday* about nine a Clock in the morning, yet by providence, and the help of Neighbours, it was saved, before any harm was done.

Mr. *Campbel*, being thus wearied, and vexed, both in the day, and in the night time, went to the *Minister*, desiring him, to let his son *Thomas* abide with him for a time, who condescended, but withal assured him, that he would find himself deceived, and so it came to pass: for, notwithstanding that the child was without the family, yet were they, that remained in it, sore troubled both in the day time, and in the night season, so that they were forced to wake till mid-night, and sometimes all the night over. During which time, the persons within the Family, suffered many losses, as the cutting of their Cloaths, the throwing of Peits, the pulling down of Turff, and Feal from the Roof, and Walls of the House, and the stealing of their Apparel, and the pricking of their flesh and skin with Pins. The *Presbytery* having conveened at the place, for a solemn Humiliation, perswaded *Gilbert Campbel* to call back his Son *Thomas*, notwithstanding of whatsoever hazard might follow. The Boy returning home, affirmed that he heard a voice speak to him, forbidding him to enter within the house, or into any other place where his Fathers Calling was exercised. Yet he entered, but was sore abused, till he was forced to return to the *Ministers* house again.

Upon *Monday* the 12 of *February*, the rest of the Fami-

ly began to hear a voice ſpeak to them, but could not well know from whence it came. Yet, from evening till midnight, too much vain diſcourſe was kept up with the *Devil*, and many idle and impertinent queſtions propoſed, without that due fear of *God*, that ſhould have been upon their Spirits, under ſo rare and extraordinary a trial. The *Miniſter* hearing of this, went to the houſe upon the *Tueſday*, being accompanied with ſome Gentle-men, who after Prayer was ended, heard a voice ſpeaking out of the ground, from under a bed, in the proper Countrey Dialect, ſaying, *Would ye know the* Witches *of* Glenluce? *I will tell you them*; and ſo related four or five perſons names, that went under an evil report. The ſaid *Gilbert* informed the company, *That one of them was dead long ago.* The *Devil* anſwered, and ſaid, *It is true, ſhe is dead long ago, yet her ſpirit is living with us in the world.* The Miniſter replied, ſaying, (though it was not convenient to ſpeak to ſuch a perſon) *The Lord rebuke thee Satan, and put thee to ſilence; we are not to receive any information from thee, whatſoever fame any perſons go under. Thou art but ſeeking to ſeduce this Family: for* Satans *Kingdom is not divided againſt it ſelf.* After which all went to Prayer again, which being ended (for during the time of Prayer no trouble was made) the *Devil* with many threatnings boaſted and terrified the Lad *Thomas*, who had come back that day with the *Miniſter*, *that if he did not depart out of the houſe, he would ſet all on fire.* The *Miniſter* anſwered, and ſaid, *The Lord will preſerve the Houſe, and the Boy too, ſeing he is one of the Family, and hath Gods warrand to tarry in it.* The *Devil* anſwered, *He ſhall not get liberty to ſtay: he was once put out already, and ſhall not abide here, though I ſhould purſue him to the end of the world.* The *Miniſter* replied, *The*

Lord

Lord will ſtop thy malice againſt him. And then they all prayed again, which being ended, the *Devil* ſaid, *Give me a Spade and a Shovel, and depart from the houſe for ſeven dayes, and I ſhall make a grave, and ly down in it, and ſhall trouble you no more.* The *Good-man* anſwered, *Not ſo much as a Straw ſhall be given thee, through Gods aſſiſtance, even though that would do it.* The *Miniſter* alſo added, *God ſhall remove thee in due time.* The *Devil* anſwered, *I will not remove for you, I have my Commiſſion from Chriſt to tarry, and vex this Family.* The *Miniſter* anſwered, *A permiſſion thou haſt indeed, but God will ſtop it in due time.* The *Devil* replied, *I have* (Mes. *John*) *a Commiſſion, that (perhaps) will laſt longer than your own.* After which, the *Miniſter* and the *Gentlemen* aroſe, and went to the place where the voice ſeemed to come from, to try if they could find any thing. And after diligent ſearch, nothing being found, the *Gentlemen* began to ſay, *We think this voice ſpeaks out of the children*, for ſome of them were in their beds. The *Devil* anſwered, *You lie, God ſhall judge you for your lying, and I and my Father will come and fetch you to hell, with* Warlock-theeves; and ſo the *Devil* diſcharged the *Gentlemen* to ſpeak any, ſaying, *Let him ſpeak that hath a Commiſſion* (meaning the *Miniſter*) *for he is the Servant of God.* The *Gentlemen* returning back with the *Miniſter*, they ſat down near to the place whence the voice ſeemed to come from, and he opening his mouth, ſpake to them, after this manner. *The Lord will rebuke this Spirit, in his own time, and caſt it out.* The *Devil* anſwering, ſaid, *It is written in the 9 of* Mark, *the Diſciples could not caſt him out.* The *Miniſter* replied, *What the Diſciples could not do, yet the Lord having hightned the Parents faith, for his own glory did caſt him out, and ſo ſhall*

be thee. The *Devil* replied, *It is written in the* 4 *of* Luke, *And he departed, and left him for a season.* The *Minister* said, *The Lord in the dayes of his humiliation, not only got the victory over Satan, in that assault in the wilderness, but when he came again, his success was no better, for it is written,* Joh. 14. *Behold the Prince of this world cometh, and hath nothing in me ; and being now in glory , he will fulfill his promise, and God shall bruise Satan under your feet shortly,* Rom. 16. The *Devil* answered, *It is written,* Mat. 25. *There were ten Virgins, five wise, and five foolish ; and the Bridegroom came: The foolish Virgins had no Oyl in their Lamps, and they went unto the wise to seek Oyl ; and the wise said, Go and buy for your selves : and while they went, the Bridegroom came, and entered in, and the door was shut, and the foolish Virgins were sent to hells fire.* The *Minister* answered, *The Lord knows the sincerity of his servants, and though there be sin and folly in us here, yet there is a fountain opened to the house of* David *for sin and for uncleanness , and when he hath washed us there, and pardoned all our sins, for his Names sake, he will cast the unclean spirit out of the land.* The *Devil* answered and said, *That place of Scripture is written in the* 13 *of* Zechariah, *In that day I will cause the Prophets, and the unclean spirit, pass out of the land ; but afterwards it is written, I will smite the Shepherd, and the Sheep shall be scattered.* The *Minister* answered and said, *Well are we, that our blessed Shepherd was smitten, and thereby hath bruised thy head ; and albeit in the hour of his sufferings, his Disciples forsook him,* Mat. 26. *yet now having ascended on high, he sits in glory, and is preserving, gathering in, and turning his hand upon his little ones, and will save his poor ones in this Family from thy malice.* The *Minister* returning back a little, and standing upon the floor, the

the *Devil* ſaid, *I knew not theſe Scriptures, till my Father taught me them. I am an evil Spirit, and Satan is my Father, and I am come to vex this houſe*; and preſently there appeared a naked hand, and an arm, from the elbow down, beating upon the floor, till the houſe did ſhake again; and alſo the *Devil* uttered a moſt fearful and loud cry, ſaying, *Come up Father, come up: I will ſend my father among you. See, there he is behind your backs.* The *Miniſter* ſaid, *I ſaw indeed an hand, and an arm, when the ſtroak was given, and heard.* The *Devil* ſaid to him, *Saw you that? It was not my hand, it was my fathers; my hand is more black in the loof. Would you ſee me? Put out the candle then, and I ſhall come butt the houſe among you like fire-balls.* After which all went to Prayer, during which time, it did no harm, neither at any other time when *God* was worſhipped. When Prayer was ended, the *Devil* anſwered and ſaid, Mes John; *if the Good-mans ſons prayers at the Colledge of* Glaſgow, *did not prevail more with God, than yours, my father and I had wrought a miſchief here ere now.* To which one of the Gentlemen replied, though a check had been given him before, *Well well, I ſee you confeſs there is a God, and that prayer prevails with him, and therefore we muſt pray to God, and will commit the event to him.* To which the *Devil* replied, *Yea Sir, you ſpeak of prayer, with your broad lipped Hat* (for the Gentleman had lately gotten a new Hat in the faſhion with broad lips) *I'le bring a pair of Shears from my father, that ſhall clip the lips of it a little.*

The night now being far ſpent, it was thought fit every one ſhould withdraw to his own home. Then did the *Devil* cry out fearfully, *Let not the Miniſter go home, I ſhall burn the houſe if he go*; and many other wayes did he

threaten. And after the *Minister* was gone forth, the *Good-man* being instant with him to tarry, whereupon he returned, all the rest of the company going home. Then said the *Devil* to the *Minister*, *You have done my bidding. Not thine*, answered he, *but in obedience to God, have I returned to bear this man company, whom thou dost afflict.* Then did the *Minister* call upon the Name of *God*, and when Prayer was ended, he discharged Mr. *Campbel*, and all the persons of the Family, from opening their mouth, in one word to the *evil spirit*, and when it spake, that they should only kneel down, and speak to God. The *Devil* then roared mightily, and cryed out, *What? Will ye not speak to me? I shall burn the house, I shall strike the bairns, and do all manner of mischief.* But after that time, no answer was made to it, and so for a long time no speech was heard. After this, the said *Gilbert* suffered much loss, and had many sad nights, not two nights in one week free; and thus it continued till *April*. From *April* to *July*, he had some respite, and ease. But after, he was molested with new assaults: and even their Victuals were so abused, that the Family was in hazard of starving; and that which they did eat, gave them not the ordinary satisfaction they were wont to find.

In this sore and sad affliction, Mr. *Campbel* resolved to make his address to the *Synod* of *Presbyters*, for advice and counsel what to do, which was appointed to conveen in *October* 1655, namely whether to forsake the house and place, or not? The *Synod* by their Committee, appointed to meet at *Glenluce* in *Feb.* 1656, thought fit, that a solemn Humiliation should be kept thorow all the bounds of the *Synod*, and amongst other causes, to request *God* in behalf of that poor afflicted Family, which being carefully

done

done, the event was, through the Prayers of his People, that his trouble grew less till *April*; and from *April* to *August*, he was altogether free. About which time, the *Devil* began with new assaults, and taking the ready meat that was in the house, did sometimes hide it in holes by the door-posts, and at other times did hide it under the beds, and sometimes among the Bed-cloaths, and under the Linnings; and at last, did carry it quite away, till nothing was left there, save Bread and Water to live by. After this, he exercised his malice and cruelty against all the persons of the Family, in wearying them in the night time, with stirring and moving thorow the house, so that they had no rest for noise, which continued all the moneth of *August* after this manner. After which time, the *Devil* grew yet worse, and began with terrible roarings, and terrifying voices, so that no person could sleep in the house, in the night time, and sometimes did vex them with casting of stones, striking them with staves on their beds in the night time: and upon the 18 of *September*, about midnight, he cried out with a loud voice, *I shall burn the house*; and about three or four nights after, he set one of the beds on fire; which was soon extinguished, without any prejudice, except the bed it self: and so he continued to vex them.

OBSERVATION XXI.

I Need not make any apology for inserting this Observation, even though it be well known upon the matter in this place. But because the thing is extraordinary, and that there are many who have not so much as heard of it, I have therefore presumed to mention it here. The matter is shortly this. There's a certain Woman, named *Mistris Low*, who had a real and true Horn, growing upon the right side of her Head, three inches above her right Ear. The length of it is eleven inches, and two inches about. The form is crooked spirally. It is convex on the outer side, and somewhat guttered in the inner side. It is hard and solid, and all very near of the same greatness. It is not hollow within, as horns are ordinarily, but full, yet it seems to be spongious as a Cane is. It was seven years in growing, and was cut off in *May* 1671, by *Mr. Temple*, an expert Chirurgeon here at *Edinburgh*.

OBSERVATION XXII.

THis Observation is for finding the *Primum vivens* in *Animals.* Albeit I doubt not but the *red Spirit*, or *Blood*, in most *Terrestrial Animals*, is the first product of the *Primigenial juice*, and therefore not improperly named the true *Callidum Innatum* of these Creatures, by the Noble and Ingenious *Harvey*, in his Book *de Generatione.* Neither do I scruple to yeeld, that the *Heart*, and appendent Vessels, are the first formed, and perfected parts in the hotter kind of *Animals* : yet I am confident to affirm, that in many of the colder, and moister kinds of *Aquaticks*, if not in all, neither the redness and heat of the

Vital

Vital Spirits, nor the formation of the *Heart*, *Liver*, &c. are previously requisite, to the structure and existence of the other parts; seing the light of life, which at first inhabited the clear and Cristalin radical moisture, before the formation of any particular part, doth alwayes move in every living creature, according to their particular exigency, without any absolute dependency upon any one part, or member (excepting singular conditions, wherein they may be stated) as to its substance, light, and motion: there being in some *Animals* a simple undulation, in others a slow creeping, but in the more perfect, an impetuous running, or rather flying of the *Vital Spirits*, necessarily required for illumination and vivification of the whole.

For confirmation, I shall give you this singular Experiment. About the middle of *March*, the sperm of *Frogs* (according to the number of *Prolifick Eggs* therein contained) sends forth a multitude of small round Creatures, covered with a black, and moveable *Frock*, which about the end of *March*, and beginning of *April*, by the Gyrations of a Tail behind, like a Rudder, do slowly move their bodies in the Water. At this time having opened severals of them, I found nothing (apparent to the naked eye) but a clear thin Membran, under the fore-named black *Frock*, within which were contained a clear Water, and some small Fibres like Intestines, and in the fore-part a small orifice like a mouth. About the middle of *April*, its motion is more vigorous, and the *Tripes* within are most evident, lying in a very fine circular order, but as yet, there is no Vestige of *Heart*, *Blood*, or *Liver*, &c. About the middle of *May*, the feet formed like small threeds, appear thorow the black *Coat*: within the Breast, the Heart is then visible, of a white and Fibrous substance, the Liver

is white,and the Gall therein eaſily diſcerned. But (which is the head of this Experiment) the Vital Spirit, in form of a clear and pure Water, is manifeſtly received by the Nervous Heart, and by the contraction thereof tranſmitted to all the Body, thorow white tranſparent Veſſels, which being full of this Liquor, do repreſent the *Lymphatick*, rather than the *Sanguiferous Veins*. Laſt of all do the *Pneumatick Veſicles* (which in this *Amphibium* ſupply the place of the Lungs) ariſe in the Breaſt, after whoſe production, the Lympid and Cryſtalin Liquor, while the Heart is turgid therewith, ſeems to be red and fiery, but in the other Veſſels, it is of a faint pale colour, untill (about, or near the end of *June*) the *Frock* being caſt off, and a perfect *Frog* formed, the whole Veſſels are full of Blood, or a red ſubſtance very thin, and clear: the Liver, and *Pneumatick Veſicles*, &c. become red, and Roſy; ſo that the Blood in this *Amphibium* (which in the more perfect Animals is firſt compleat) ſeems to be the laſt part in attaining its perfection.

That *Salmonds*, and great *Trouts* have an aqueous liquor which runs thorow their *Arteries*, and *Veins*, before their Blood attain the true conſiſtency, and ſaturat tincture I am certain: whether it hold in many others, I ſuſpect, but dar not affirm. Hence it may be (if mens obſervations, were frequent in all kind of *Anatomical inſpections*, in ſeveral *Embryo's* of every *ſpecies*) it would be found evident, that the Blood in all theſe, called ἐναίμα, hath its immediat original from a ſimple homogeneous, and uniform liquor, and doth by gradual and frequent influences of the vital ferment of the heart, receive at length the full tincture,eſſence, and ſubſiſtence requiſite for vivification, and illumination of the whole members.

Whether

Whether this Experiment doth not ſufficiently impugn the univerſality of the hearts firſt living, the original of the Gall from the fervour, and ebullition of the Blood, the production of the Blood by the Liver, and many other ancient errors, let any judge, who will but take pains to make and compare *Harveys* trials *de ovo*, with this of the *Porwigl* or *Gyrinus*, *ab ovo*.

Yea, if the aqueous liquor, be not one with the vital Spirit, and ſubſequent Blood, then my eyes, and taſte are altogether erroneous.

Moreover, it were to be wiſhed, that *Phyſitians* would not ſimply ſtand upon the *Galenick ſuppoſitions* of the four alledged Components of the Blood, nor any ſuch, or equivalent fancies of the latter *Chymiſts*; but that they would ſeriouſly examine the firſt original, and riſe thereof from the *Primigenial juice*, or *liquamen*, the progreſs, and perfection of its tinctures, how many renovations, or new tinctures it is capable of; the vaſt difference between the Blood of old and young *Animals*, (though, it may be, they are both *univocal* ſubſtances, while in their integrity within the Veſſels) with the *ſpecifick* diſcriminations, not only of that of any one *Aquatick*, from any *Volatil*, or *Terreſtrial*, but likewiſe of any one *Species* living in the ſame Element, with theſe that enjoy the ſame Aliments, but of a different *Species*. And laſtly, the variety of particular conſtitutions, and ſingular properties of individual *Animals*, radicated in the fountain of life, or firſt original of the Blood. If theſe things, and many more, were truly inquired after (though the Cook be ſometimes neceſſitated to throw away ſome of the Broth with the Scum) I doubt not but the *Neoterick* Invention of *Transfuſion of Blood*; would prove altogether ridiculous, and the ancient miſtake of too

much *Profusion* of this treasure by *Phlebotomy*, might suffer some reasonable checks from infallible Experience, and sound reasons, not here to be mentioned. There are truths in Natural Philosophy, which (I doubt not) but sound reason and experience will convince the vain world of in due time.

OBSERVATION XXIII.

THis Observation is concerning the aliment and growth of Plants. The inquisitive wits of this, and the last age, having rejected the old opinion of the earths nourishage, having rejected the old opinion of the earths nourishing of Plants, or being converted into their aliment, have made many laudable Experiments for finding out the materials, and means of their growth; and vegetation, such as Sir *Francis Bacon*'s *Observe of Germination*, *Helmonts* of a *Willow*, and the Noble *Mr. Boyl*'s of a *Gourd*, &c. For though a Tree be cut down, and the root thereof wax old in the earth, and the stock die in the ground, yet through the sent of Water, it will bud, as *Job* speaketh, *Chap.* 14. 7, 8, 9. I shall add a short remark of a Willow growing without earth. Upon the 13 of *April* 1662, I set a top branch of the *Peach-leaf'd Willow* in a Glass-viol, among 12 ounces of pure Spring Water, with three small buds upon the top thereof, scarce yet discernable. The first ten or twelve dayes, little white specks appeared upon the sides of the Willow, like small drops of *Quick-silver*, or like the first Bubbles that arise upon the fermentation of Ale or Wine, but no consumption of the Water all this time. Indeed the *Gemms*, which stood three inches above the Water, did visibly swell about the twelfth day. About the fifteenth day, I perceived small white roots within the

Water,

Water, upon ſeveral places of the *Plant*, and obſerved the Liquor grow ſomewhat thick, and decay in bulk conſiderably. Having perceived this, I took another Glaſs of the ſame bigneſs, with that wherein the *Willow* grew, and having filled both top-full with Spring Water, I obſerved clearly the conſumption of the Water wherein the *Plant* ſtood, to be ſo great, that during *May*, *June*, and a great part of *July*, every week (at leaſt) an ounce and an half, or two ounces of it were inſenſibly ſpent: whereas the other Water, ſtanding by in an open Veſſel of the ſame ſize, made not waſte of one ſpoonful in a whole moneth. About the middle of *Auguſt*, the Water turned very thick, and green, like that whereon *Duck-weed* uſeth to grow, and the fair white roots were all obſcured from the ſight, although the Veſſel by the multitude of roots was not capable of the third part of Water it received at firſt. At this time the branches were advanced to half the bigneſs, and a much greater length, than the whole ſtock, at its firſt planting; and the leaves of as freſh a verdure, as any *Willow* in the fields. Thus, having obſerved, that a tree of four ounces weight, could in three moneths time, and little more, conſume inſenſibly, ſeven or eight times its own weight of pure Water, without the warm preſervation of the earth, and by its own proper digeſtion, to thicken the remnant of the Water, that it might ſerve for *lorication* of the tender fibres of the roots, I took the Glaſs, the Tree, and all, and threw them over a Window, ſuppoſing it needleſs to recruit the Water any more, and judging it impoſſible without the warm guard of the earth, that the naked Tree could be preſerved in Winter: yet it had the good fortune to fall among ſome thick Herbs in the corner of a little Garden, where (after it had lien all Winter) it

was,

was found, and brought back to me, the branches fairly budding in *April*, the whole Tree fresh and green, yet very little Water was left in the Glass, by reason, as I judged, it had fallen upon its side. Then I endeavoured to keep Water about it, but the Stock filling the neck of the Viol, and the Roots the whole body thereof, the starved *Plant* died in *May*, after it had lived a whole year without earth. From this it would seem, that this kind of Tree, (and it may be, many moe) doth dissipat insensibly six times more Liquor, than it doth assimilat, and by consequence, that a great quantity of moisture is necessary for maintainance of great Woods. Neither is there any way so advantagious for draining moist ground, where there are no living Springs, as that of planting abundance of Timber, which will best agree with that kind of soyl: for by this means, what was formerly noisome, and superfluous, is now converted partly into the useful aliment of the Timber, and partly sent abroad in insensible exhalations, which (according to the nature of the emitting *Plants*) prove either very noisome, or wholsome to the Neighbour-Inhabitants. Great care therefore would be had in the choise of such Trees, as are to be planted in such moist ground, as are near to mens dwellings, or places of concurse. They are not fools, who prefer *Firs*, and *Lime-trees* in their *Avenues* to *Oak* and *Elme*. Let the effects of the *Atomical* exhalations of *Alder* and *Oak* upon fine Linnen, and white Skins be more particularly noticed.

Having spoken somewhat of the aliment and growth of *Plants*, I shall in the next place give a short hint at the motion of their aliment, especially of Trees. That the alimentary juice of *Plants*, is much thinner, than that of *Animals*, no man, I suppose, will deny, seing *that* is conveyed

veyed thorow the trunck, or body of the *Plants*, by in-perceptible pores; but *this* (for the most part) is sent thorow all the members, through patent and manifest Vessels. But how the nourishing, and vital juice in *Plants* doth move, and by what passages, hath not yet been made known, by any that I have seen. I made once a few Observations, for trying of the motion of the aliment of Trees, which bred in me this conjecture. The nutritive juice of Trees is transmitted both to the roots and branches, through the heart, or pitch, and woody pores of the Timber, and when it is come to the extream parts, it returns again from the tops of the roots and branches, between the bark and timber, into these forenamed interior passages, and so back to the extremities again, and that continually, so long as the life remains. And because the substance of that skin, or bark, which invests the fibres of the root, is more open and porous, than that which is upon the outward branches: therefore it seems, that so much as is superadded to the stock of the former aliment, from the earth, is conveyed to the heart and pitch, by means of, and together with, that part of the retrograd juice, which returns from nourishing, and enlivening the timber of the root-branches, (for it is an easie Experiment, to make the top of any Tree become root, by laying it down) and receives the impressions of the life of the Tree, common to the whole mass of alimentary juice, like the *Chyll* in *Animals* mixed with the blood of the *Veni-cave*, before it come to the heart.

This motion is not to be thought alwayes alike swift, or of equal celerity: for the vital juice of the Tree becomes so thick and oleagenous in the Winter, that the motion thereof to the outward, is scarce discernable (though the preparation of the *Gemmes*, both for leaves and flowers,

are observed by the curious, and can be distinguished, even in the coldest seasons) and the returns inward are in so small quantities, that they are rather like vapours, than liquid juice. Indeed, some Trees, when their root-branches are cut (even in Winter) will yeeld no small quantity of an acid liquor, which by addition of the recent *Lessas* from the earth, smells evidently of the Matrix, from which it did proceed. Moreover, the passages especially from the branches to the Trunk, are so straitned and contracted, that the bark cleaveth to the Timber, as every Wood-man knows. But so soon as the warm Spring hath attenuated the ever-flowing juice in the whole Tree, then doth it become turgid, and more aqueous over all: the passages, and channels both in the trunk, and among the tunicles, and particular skinnes, are so palpably filled with this vital juice, that having no sufficient place to be comprehended in, it putteth forth new growths both in the top, and in the root, which may be easily seen to have more pitch than wood, and to be sealed on the extremity, with the vestiges of a future Gemm; that by the former, they may the more freely receive the vital influences from within, and by the latter, may be secured from the depredation of the external Air.

To prove the motion *ad extra*, or to the extremities of the branches; take the branch of any ordinary Tree, about the bigness of a mans wrist; make it bare near the body of the Tree of all bark, and subjacent tunicles (for every Tree according to its kind, hath moe or fewer skins, which serve for Veins, within the strong outmost Cortex) at least for the breadth of a span, or two hand-breadth. Then tye up the place, so excorticated with a *compost*, made of horse-dung mixed with earth; let it stand so from *May*, till

till *November.* Then cut off the branch, a little above the *Compoſt*, near the body of the Tree, and you ſhall find it living and freſh, like the reſt of the branches: yea, ſmall roots ſhall evidently appear to have come forth under the *Compoſt* near the bark, but not under the bared place. This branch in many kind of Trees being planted, will hold, though not in all. I ſay then, ſeing the foreſaid bough is nouriſhed from *May* till *November*, it is neceſſary, that it receive nutriment from the body of the Tree, by the internal poroſities thereof: for the bark being diſcontinued by *excortication*, can ſend nothing upward towards the top of the bough; and if it received nothing from the root, it would wither in a few dayes. Yea, leave the diſcovered part naked, but for a few dayes, and of neceſſity the branch dieth, the aliment thereof being exhauſted by the Air, before it can reach the extremities of the bough.

That the *Vital Balſome* of the Tree returns from the extremities by the internal bark, and inward ſuperfice of the external, together with the ſmooth outward part of the trunck, although the neceſſity of both timber and bark in all *Inciſions*, and *Inoculations*, might perſwade the judicious, and the viſible courſe of the juice of the *Sycamor* in *February*, and of the *Birch* in *March*, upon the cutting of any ſmall branch, might convince any curious beholder; yet the *knot* or *callus*, that is made upon grafted Trees, will better inform the ignorant: for this *knot* being alwayes upon the ſhoulder, or root of the Graff, and never upon the top of the Stock, doth evince clearly, that it is made by *reſtagnation*, of the deſcending, and not of the aſcending juice: otherwiſe, why doth it not ſwell the top of the Stock, as well as the root of the Graff? Or why doth it not extuberat in any other place of the Graff? Theſe

are accidental *varices*, which can hardly be ſhunned in Imping, ſeing the top of the Stock (except when it is very young and ſucculent) doth not receive ſo kindly, as it ought, the retrograd ſap, although all that is ſent out to the Graff muſt aſcend thorow the pores of the Stock. Hence many times a conſiderable part of the Stock is mortified, becauſe although abundance of aliment aſcends to the head or top thereof, yet no more of it goes to the branches, but what is beſtowed upon the Graff, a great part of the reſt being exhaled by the Air (eſpecially in big Stocks) and conſequently, the place defrauded of its nouriſhment: no other wayes than when the motion of the vital ſap faileth, either in the whole, or in part, a total decay or particular mortification of ſome part neceſſarily follows, as in the Stemms of annual Plants, and mortified tops of the *Ectrapelous* branches (that I may ſo call them) of *Willows*, *Plumbs*, &c. we may obſerve every *Autumn*.

OBSERVATION XXIV.

Sir,

"I Was not a little ſurpriſed, at the receit of yours, when "I had conſidered your deſire in it, being preſt with two "difficulties, which ſeemed equally hard to evite. The "one, to give you my judgement in a matter wherein I "have been ſo little converſant my ſelf, and have had the "ſteps of no other to follow, never one having hitherto "touched that ſubject in writting; I mean of *Coals*, and "other *Minerals* of that nature, their *Courſe*, and other "things relating thereunto; the obſervation whereof (I "grant) wants not its own pleaſure, and uſefulneſs. The "other, to refuſe the deſire of a friend, when importuned,

"to

" to whom I owe my ſelf, by many obligations. This laſt
" having prevailed, hath determined me to aſſay the over-
" coming of the firſt. And though I am confident, what
" account I can give you, ſhall give but very little ſatis-
" faction: yet I adventure to offer it, ſuch as it is, very
" freely in the following diſcourſe, wherein you are not to
" expect, that I will meddle with ſome queſtions, there-
" anent, which might be more curious, and pleaſant, then
" profitable, or ſatisfying, ſuch as, if *Coal*, and *Free-ſtone*,
" which keep one *courſe*, and have the ſame accidental
" qualities, have been created in the beginning, in their
" perfection, as wee now find them, and ſince that time
" only preſerved, as they were created for the uſe of men,
" to whom all ſublunary things were made ſubſervient?
" Or, if they have been but produced gradually, as they
" ſpeak of *Gold*, and other *Minerals*, by the influence of
" the *Sun*, in the bowels of the Earth? And if their pro-
" duction be of that nature, out of what matter they are
" formed? Theſe things being above my reach, I ſhall leave
" their inquiry, to thoſe that are knowing in the ſecrets of
" Nature, and ſhall therefore give you a narration, of
" what either I have obſerved of theſe things, which oc-
" curr in the *Winning* of *Coal* in my own experience, or by
" converſing with others of more experience than my ſelf,
" in doing whereof, I ſhall follow this Method.

Firſt, I ſhall ſpeak of theſe things that are common to all *Coal*, wherein they all agree, and which are, as it were, *eſſential* to all, and of there differences, which are but accidental, and gradual ſometimes, and yet are abundantly conſpicuous, and cauſeth different effects in the *working*; as their *Dipps* and *Riſe*, and *Streek*, for ſo are they termed.

Secondly, of ſome things, which are but accidental to *Coal*,

and yet ſo ordinary, that ſcarcely any is found without them, in leſſer or greater degrees; ſuch are *Gae's*, and *Dykes*, that alter the natural *Courſe* of the *Metalls*, very incident to every *Coal*, though in ſome leſs frequent, conform to the nature and kind of the ground, where the *Coal* is.

Thirdly, I ſhall ſpeak ſomething of *Damps*, and of their different cauſes, and effects: of *Wild-fire*, and other ſuch like things, which are met with in the working of *Coal*.

And laſtly, of the beſt way for trying grounds to find *Coal*, where never any hath been hitherto diſcovered: of carrying on of *Levels*, for draining the water of *Coal* and making it workable.

It is to be coſidered, that all *Free-ſtone*, though of different natures, hath the ſame *courſe*, with the *Coal*, that ly either above them, or below them, except it be accidentally, interrupted: therefore, whatſoever is ſpoken of the one, is applicable to the other. And ſo we find in *Digging* or *Sinking*, that after the *Clay* is paſt, which keeps no *courſe*, all *Metals*, as *Stone*, and *Tilles* (which are *Seems* of black Stone, and participat much of the nature of *Coal*) ly one above another, and keep a regular *Courſe*; wherein the three things moſt remarkable are their *Dipp*, and *Riſe*, and their *Streek*, as it is termed.

The *Dipp*, and *Riſe*, are nothing but a declining of the whole body of the *Metalls*. And this general holds, that all of them from their *Center* riſes, till they be at the very ſurface of the *Earth*; ſome only at a foot or two foot, ſome at an ells diſtance from the ſurface, which is here termed a *Cropping*: and whether *Coal* or *Stone*, the nearer they come to the ſurface, the ſofter they become, till at

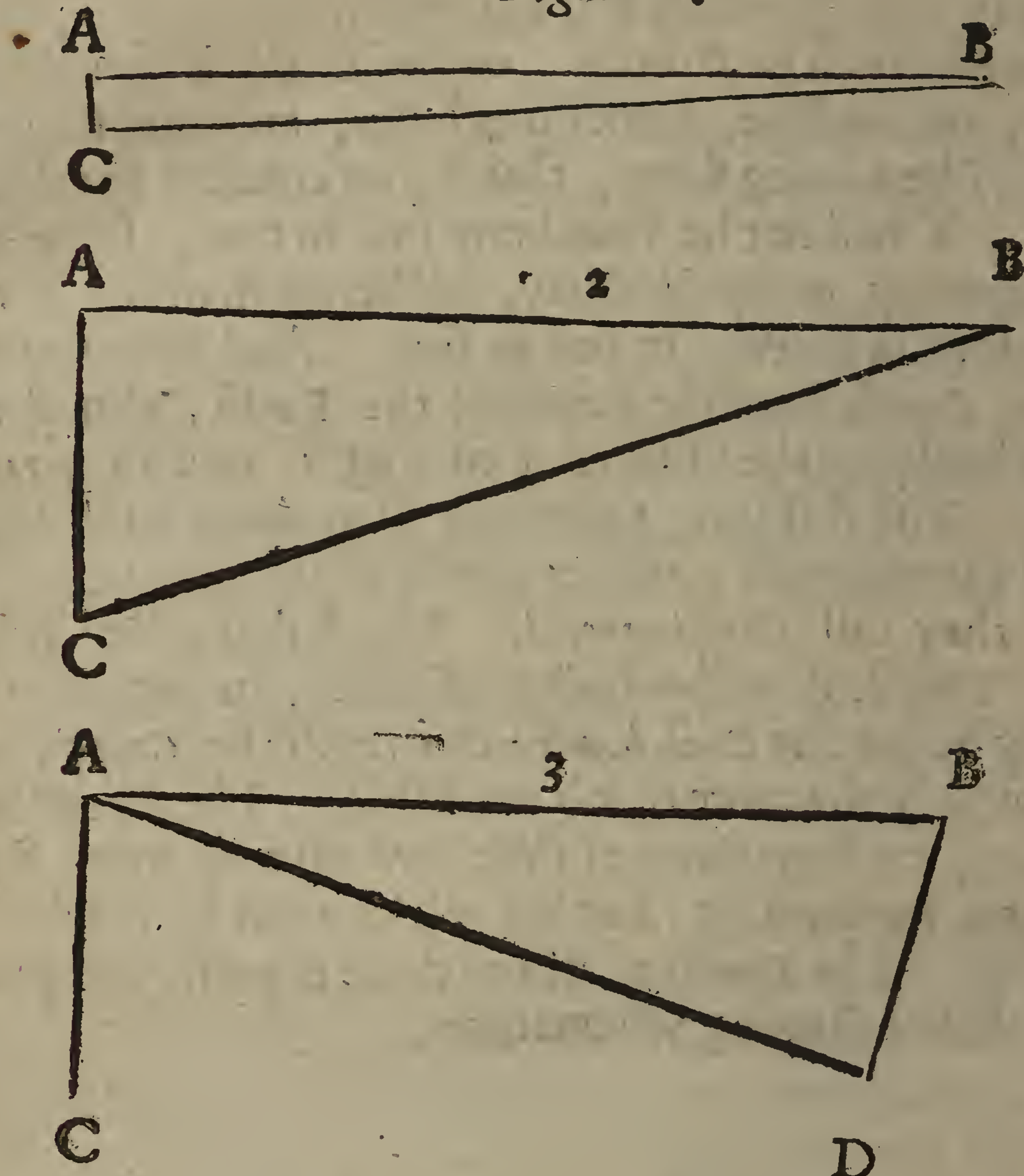
laſt

laſt they are converted, if it be a *Stone*, to a very *Sand*, and if *Coal*, to a *Droſs*, which will not burn.

This declining or *Dipping*, of the *Coal*, is ſometimes greater, and ſenſible, ſometimes leſſer, and almoſt inſenſible. There being ſome, that if you conſider the declination, it will not be found one foot in ten; ſome one foot in twenty, or one in thirty. Whereas in others it will be one foot in three, or one in five. And ſometimes it hath its *Courſe* from the *Center* of the *Earth*, almoſt in a perpendicular to the ſurface, it cutting it, near to a *right Angle*. The firſt ſort, they term *Flate-broad-coal*, in regard of the plainneſs, and evenneſs of its *Courſe*. The next, they call *Hinging-coal*. The laſt is called *Edge-Coal*. The firſt is the moſt profitable, in regard, that it's long before the *Coal-hewers* can reach the *Cropp*, and conſequently the more of it is workable. The ſecond and third ſort, are ſometimes of their own nature, more firm, and fitter for burning, but leſs of them can be reached in working. The *Courſe* of all the three is moſt perceptible in the three following Schematiſms.

Figure

Figure 1.



In all the three Figures, the point B is the *Cropp* of the *Coal*. The Line B C is the body of the *Coal* declining or the *Dipp* from the *Cropp*. A C is the perpendicular, falling from the Horizontal Line, whereby the true declination or *Dipp* of the *Coal* is found. So that after you have found your *Coal* at B, you must set down your *Sink* at the point A. In the *Flat-broad-Coal*, which we suppose only to decline, three fathoms in sixty; the *Sink*, that answers to the perpendicular A C, will be of deepness three fathoms.

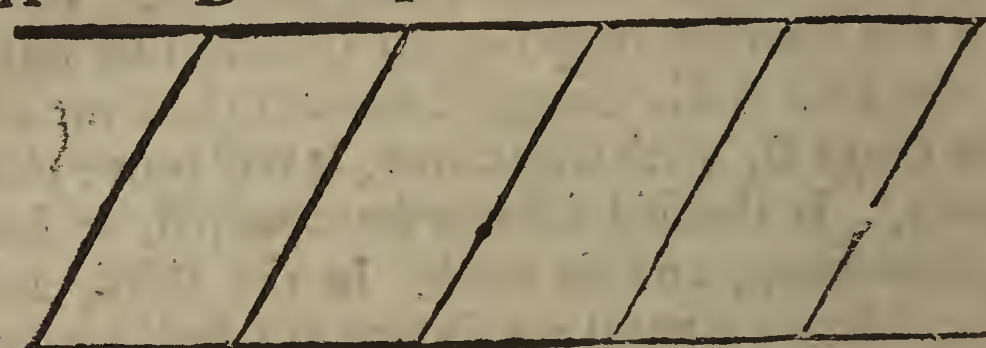
thoms. If the diſtance B A, be ſuppoſed to be 120 fathoms alongſt the *Graſs*, or ſurface, then will the deepneſs of the *Sink* be ſix fathom, and ſo forth. In the ſecond, if the *Coal* be ſuppoſed to decline one fathom in three, the *Sink* A C, being ſet down at the ſame diſtance from the *Cropp* B, with the former, it will prove thirty fathom deep. If the ſaid diſtance be doubled, it becomes ſixty fathom deep, and ſo forth. In the third, keeping that ſame diſtance alongſt the ſurface, you ſhall not encounter the *Coal* with a Perpendicular *Sink*, becauſe of its great declination, and therefore through want of *Air*, and other difficulties, you cannot dig ſo deep, as is neceſſary to that effect, except the *Sink* ſhould be made to decline, as doth the *Line* A D. All theſe *Dipps* are to be ſeen in ſeveral places of *Lothian*. The firſt is moſt conſpicuous in the Earl of *Wintons* ground at *Tranent*, where the *Coal*, and other *Metals* are extraordinary flat and even. The ſecond is within the ſaid Lordſhip of *Tranent*, in a piece of ground, called *Weſter-Fauſide*. The third in *Lonhead* of *Laſwaid*, which pertains to Sir *John Nicolſon* of *Nicolſon*: and in many other places, one may ſee very different declinations, who is curious to obſerve them.

From this general poſition of the *Dipp*, and *Cropp* of all *free Metals*, there is one conſequent, which is no uncouth Obſervation, namely that theſe *Metals* riſing from their *Dipp* to a *Cropp*, every one of them riſeth in their proper courſe, if none of theſe things whereof we ſhall treat hereafter interveen, and make an alteration, that is the *Coal* or *Stone*, which is loweſt, comes farreſt out in its *Cropping*, which is eaſily underſtood by the ſubſequent Schematiſm.

Wherein

Figure 4.

A D F H K M

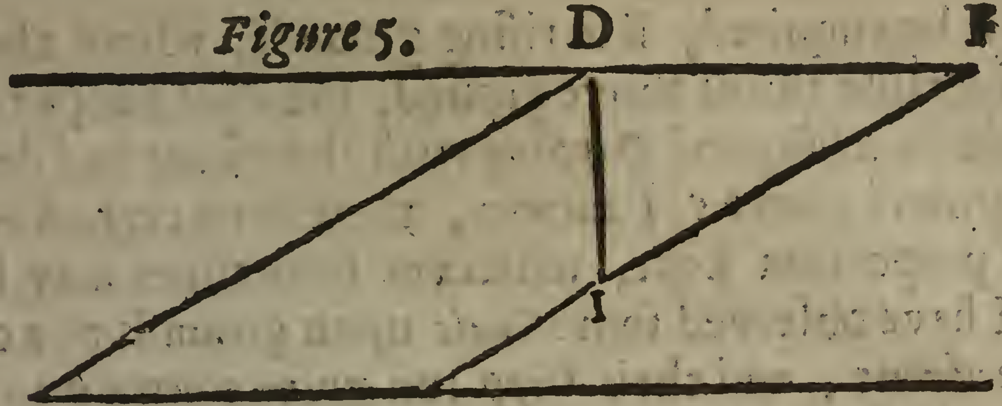


C E G I L

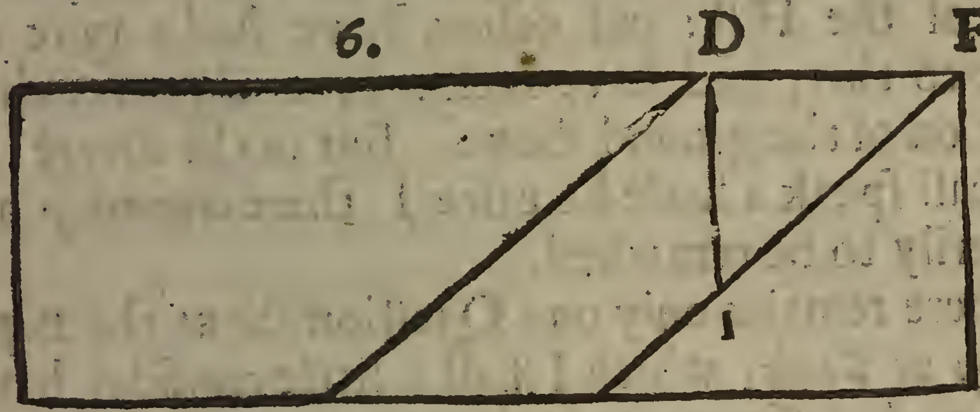
Wherein the Line AM represents the surface of the *Earth*. CD. EF. GH. IK. LM, are so many several *Metals*, lying in *course* one above another. Suppose CD were a *Stone*, and the *Roof* of the *Coal* EF (for so they term the *Stone*, immediatly next above the *Coal*) and GH, IK, were other two *Stones*, interveening between the *Coals* EF, and LM, then if the *Cropp* of the uppermost *Coal* be found at F, the *Crop* of the *Stone* above it, must be found back, at the point D, and the *Cropp* of the *Coal* under it, which is LM, must be found at M. And this distance of *Cropp* is proportioned by the length of the perpendicular between them, and the quantity of their declination. For, the more even and flat a *Coal* is in its *course*, and other *Metals*, above and below, the farder doth the *Cropp* of the lowest *Coal* advance before the *Cropp* of the uppermost. For illustration whereof, let us suppose in two several grounds, two *Coals*, between which, there is an equal distance of perpendicular. And suppose the *Metals* in the one ground to decline at 13 to 24, the other at 13 to 16, then will the distance between the *Cropps* in the two grounds be very considerable, as may be represented by the two following Figures.

Figure

Figure 5.



6.



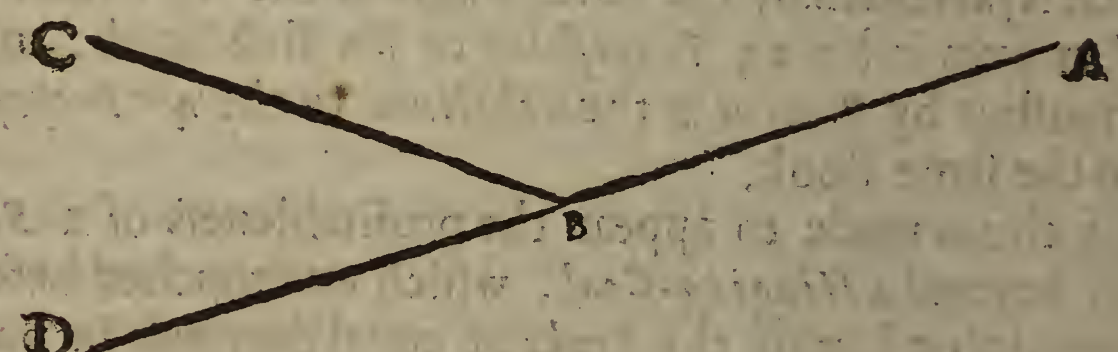
Suppoſe then, that D I, is of equal length in both *Triangles*, which is the perpendicular, between the two *Coals*: yet D F in the fifth Figure, is much longer than D F in the 6. And the reaſon is evident, becauſe the *Angle* D I F, in the 5, is greater then the *Angle* D I F in the 6: and therefore the *Baſe* D F, which is *ſubtended* by the greater *Angle* in the 5, muſt be greater then the *Baſe* D F, which is *ſubtended* by the leſſer *Angle* in the 6, which *Euclide* proves in his 24 *Propoſition* of his firſt Book, and is demonſtrat by *Proclus* in the *Scholium* to the 4th *Propoſition* of the ſame Book.

By this is made to appear the profitableneſs of a *Flat-Coal*, beyond a *Hinging-Coal*, which was touched before, in regard that having the *Sinks* of equal deepneſs in both, there is much more of the *Flater-Coal* to be wrought, before it *Cropp* out, then of the *Hinging*, as there is a difference between the Lines D F in the firſt and ſecond Figure, or between the Lines I F, in the ſame.

If it be enquired, if in rising grounds, where there is a considerable ascent above ground, the *Coal* keeps a proportion in its *Rising* and *Dipping* with the ascent and descent of the ground above? I answer, there is no certain and constant proportion kept, whatever sometimes may happen. For I have observed some *Coals* upon grounds of a considerable ascent, and their *Dipp* run quite contrary to the descent of the Hill: and others have had a quite contrary *course* to that, and have declined, or *dipped* with the declination of the ground above. But in the *Streek* (whereof I shall speak a little hereafter) there is more proportion ordinarily to be remarked.

There remains only one Question about the *Dipps*, and *Risings* of *Coals*, which I shall a little consider, having encountered different judgements anent it, in conversing with persons, who had experience in *Coal*, viz. whether *Coal* and other Metals, after they have declined such a length from their *Cropp*, suppose from *West* to *East*, take another *course*, and rise to the same point, to which formerly they dipped?

Figure 7.



As if the *Coal dipped* from A, which is the *Cropp*, to B, which should be the *Center* of that Body; and after that rise to C? Or if it should continue its declination thorow

B to

B to D, which is *Antipodes* to us? I shall not offer to determine in a matter wherein there can be so little certainty attained, but shall give my opinion, which is founded upon the experience I have had, and Observations I have had occasion to make on that Head. And first, I find in all these *Coals*, wherein no contrary *Cropp* or *Rising* could be visible, there are invincible obstructions; as either, they have been near the *Sea*, and have *dipped* that way; and so if they took any contrary *course*, the *cropping* behoved to be in the *deeps*, and so no access to trace them. Or next, they have *dipped* towards the foot of a Mountain, and so the ground above rising the same way which they declined; their *course* could not be pursued, till a contrary rising should be discerned. Or thirdly, they have encountered some *Gae*, or *Dyke*, which hath cut them off, before they came to their full *dipp*, and thus their *course* was obstructed. Now, those that have been acquainted with no other *Coals* but such, I think it not strange, if it be hard to perswade them of those things they have not seen. But besides all those kinds, I have seen others, whose contrary *rising* and *dipping* have either been visible to the eye, or demonstrable by reason. For example, I have entered under ground, as it were at the point C, at the very *Grass-cropp*, and have gone following the *dipp* of that *Coal* to the point B, at which the *course* hath altered, and carried me out at the *Grass* at A, which are two contrary points of the Compass. And that alteration of *course* was not occasioned by any *Gae*, or *trouble*, which sometimes have that effect, the ground being very clean, and good *Metals*, keeping their *course* most regularly.

There are other instances for confirming my experience, in fields, which are so large, that 'tis impossible to work

the *Coal* so far to the *Dipp*, it falling deep, and so wants *Level* for conveying water from it, or wants Air, for following it to such a deepness, as to overtake its *Center*, where it takes a contrary *course*, and yet the contrary *Cropp* hath been wrought in several places, which is evident to be a part of the same body, with the other, both by the nature of the *Coal* it self, by the *Metals* lying above it, and the *Coals* below it, all which keeping the same *Course*, except when they encounter *troubles*, which are incident to some parcels of ground, more than to others. The greatest field I know wherein this is conspicuous, is in *Mid-lothian* where is to be found, the *cropping* of a *Coal* of a considerable thickness, which is termed their *great-seam*, or *Main-coal*, and the other *Coals* lying below it, which may be traced in the order following. At *Preston-Grange* these *Coals* are found *dipping* to the N W, and *rising* to the S E, which have been wrought up to *Wallifoord*: from that along by the foot of *Fauside* Hill, the *dipp* lying in the Lands of *Inneresk*, which marches therewith on the *North*. From thence it runs through the ground of *Carberry*, every one of these grounds from *Preston-Grange*, Giving *Level* to another. From thence, through a part of the Lands of *Smeaton*, and next through a piece of ground belonging to the Family of *Buccleugh*, called *Coudon*: and through *West-houses*, which belongs to the *Earl* of *Lothian*, and at *Cockpen*, and *Stobhill*, from thence runs through to *Carington-Mill*; all which is a *course*, which in *Streek* lyes near to S W, and N W, and will be in length about eight miles. From thence, the *course* of the *Coal* turns, and is found in the Barony of *Carington*, *White-hill Ramsay*, *Gilmerton*, and from thence taking its *Dipp*, quite contrary to what it had before, the other *Dipping* N and N W,

or

or N E, according to the turn of the *Streek*, it *Dipps* there S, S E, &c. and from *Gilmerton*, it is found at *Burntstone*, a piece of ground belonging to the *Earl* of *Lauderdale*: and from thence at the *Magdalen Pans*, where the turn of the *cropp* being within the Sea, is not seen, till it be found at *Preston-Grange*, where we began to remark its *course*. The parcel of ground, under which this great body of *Coal* lyes, is of a considerable extent, it being eight miles in length, and five or six in breadth; in regard whereof many other *Coals* are found lying above the great *Coal*, the *cropps* whereof doth not come near the *Cropp* of it, by a considerable distance.

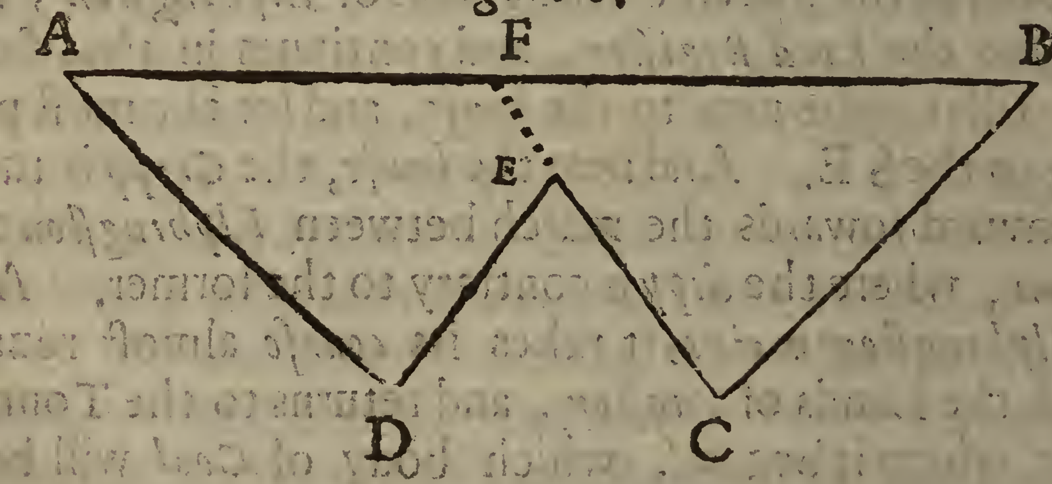
Though this instance alone, may sufficiently convince, yet I shall not be unwilling to give another. The parcel of ground, in which this *Coal* is found, is not of so great an extent, as the other, and therefore its *course* may be the more easily traced. For the greatest part, it belongs to the *Earl* of *Winton*, and lyes within the *Lordship* of *Tranent*, whose contrary *Cropps*, are most conspicuous. This great *Coal*, which is 10, or 12 foot thick (beginning at the head of the Toun of *Tranent*) where it hath been wrought, runs S W towards the march of the Lands of *Elphingston*, belonging to the *Lord Register*, and continues in that same *course*, till it come near to the *house*, and for the most part *dipping* to the S E. And near the *house*, the *Cropp* is turned downward towards the march between *Elphingston* and *Ormiston*, where the *dipp* is contrary to the former. And from *Elphingston-mains*, it takes its *course* almost round, through the Lands of *Panston*, and returns to the Toun of *Tranent* where it began, which body of *Coal* will be in length two miles, and in some places, as much in breadth. Now, I leave it to the judgement of any person, if there be

not

not more reason to perswade, that this should be the natural *course* of these *Minerals*, where such pregnable instances, to evince it, are found; then to conclude the contrary from these *Coals*, the *course* whereof cannot be followed, because of the invincible impediments, I mentioned before. However, I leave every one to be determined, by his own opinion, and shall be satisfied to injoy my own, till these of more experience convince me of the contrary.

There are some other things farder to be remarked about the *Dipp*, and *Rise* of *Coals*, which (possibly) every one hath not seen, they being so very rare, and therefore are not fit here to be passed without being considered. One is, of a *Coal*, which having that contrary *Dipp* and *Rise*, (whereof I have been speaking) in one of the *cropps*, hath not come out to the *Grass*, and *terminat*; but after it hath *risen* a considerable way in its contrary *course*, in stead of *Cropping* out, hath taken a *Dipp* towards the same point, to which it *dipped* first, and so having *dipped* to the *Center* of its *course*, it hath *risen* again, and *cropped* to the contrary point, as is to be seen in this eight Figure.

Figure 8.



Where A B is the surface of the Earth. The point B is the *Cropp* of a *Coal dipping* from N W, to the S E. From

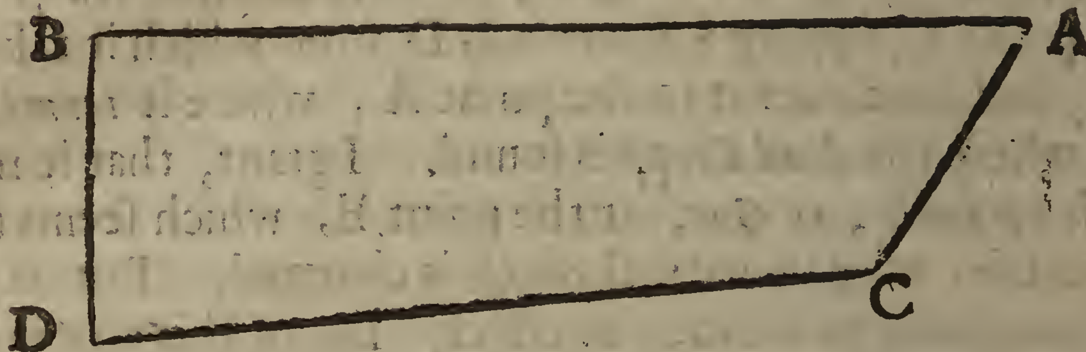
C is

C it takes its *rise*, and *course* to a contrary C*ropp*, towards the point F, where the *dead Cropp* ought to be found. But in-stead of going that length, it takes another *course* from the point E, *dipping* S E towards D, from which it takes its *rise*, and continues it to the point A, where it *terminats*, and where the *dead Cropp* is found. I grant, that it meets with a *trouble*, or *Gae*, at the point E, which seems to be the cause, why its natural *course* is changed. But its very extraordinary to see such an effect. But of this afterwards, in its own place.

There is yet another thing to be remarked, in the *dipps*, and *risings* of *Coals*, which is this. In the most part of *Coals*, that have their *course* from *dipp* to *cropp*, without the intervention of a *dyke or gae*, the declination is straight down, from the horizontal line drawn from the point of the *cropp*, to the fardest point of the *dipp*. That is, the *Coal* declining from that point in a right line, makes with the horizontal line, a *right lined angle*, *angulus rectilineus*, though in some the *angle* is more *acute*, and in others less, as is to be seen in the first, and second figures, where A B being the horizontal Line, and B the *cropp*, B C is the body of the *Coal* declining, which meeting with A B in the point B, constitutes a *right lined angle*, and where ABC in the second figure, is a greater *angle*, then A B C in the first. Yet I have seen a *Coal*, the body whereof from the *dipp*, or fardest point of declination, had its *rise* towards the *cropp* very insensibly, it being *Flatt*, and then began to be more sensible, till at last coming near to the surface of the Earth, it takes in a sudden such a *rise*; that from declining one foot of 12 or 14, it declines now one foot of three, as may be made evident from this following Figure.

Figure

Figure 9.



Where A B is the Line drawn from the extream points of the *Cropp*, right horizontal. The body of the *Coal rising* insensibly, is D C. But assoon as it comes to C, it riseth with a great ascent till it *Cropp* out at A. Here you see, that in stead of one side of a *Triangle*, which the *course* of other *Coals* in their *rising*, or in their declination makes; this *Coal* in *rising* makes two sides, namely D C, and C A, the Figure D B C A being quadrilateral. The *Coal* of this *course* was really wrought, and is yet visible in its *waste*, where there is found no *Gae* or *Dyke* to make this alteration.

These are the chief things that I have thought worthy of Observation in the *Dipps*, and *Risings* of *Coals*, and therefore I come now to touch a little the other part of their *course*, which is commonly termed the *Streek* of a *Coal*. To make intelligible to those, who are not experimentally acquainted with *Coal*, this term, or what the *Streek* is, we must lay this foundation, that the *Coal* is a *Physical Body*, and so hath its three principal dimensions, which do constitute it so, *viz*, *Longitude*, *Latitude*, and *Profundity*. Its *Latitude*, is that part contained between its extream lines, which is measurable by its surface, to which

its

its *dipping* and *rising*, though alwayes incident, yet is but accidental. Its *Profundity* is to be measured by the distance, between the two surfaces, immediatly next to it, above and below: which are termed in Coallery its *Roof* and *Pavement*, because of the resemblance they have to the *Roof*, and *Pavement* of a house. The *Longitude* is nothing else but what is termed by the *Coal-hewers*, the *Streek*. For if you imagine a Line drawn along the extream points of the *Rise*, or *Cropp* of the Coal, that is properly the *Streek* of the Coal.

There are but few things to be remarked, as to this part of Coal: only first to find how it lyes, to what points of the Compass it moves. For knowing whereof, there is this general Rule, that, having found your *Dipp* and *Rise*, to what ever Points that Course is directed, the *Streek* is to the quite contrary. For supposing a Coal *Dipp* S E, the two points, that respect the *Dipp* and *Rise*, must be S E, and N W, being the points opposite one to another. Then it must needs follow, that the *Streek* must run S W, and N E, which two *courses* divides the Compass, at *right Angles*. And therefore, where a Coal is found to have contrary *Dipps*, and *Risings*, they declining sometimes to all the Points of the Compass (whereof there hath been given two notable instances before) it must needs follow, that there be also contrary *Streeks*, and so the *Streek* of a Body of Coal is sometimes found to describe a round figure, though not perfectly circular, and somtimes a *multangular* figure. For it cannot be supposed that the *Streek* makes alwayes a right Line, between the two points, from which it is reckoned. For example, between the *Laird* of *Preston-grange* his house at *Preston-pans*, and the *Stob-hill*, there are the *Streeks* of several Coals, lying one a-

bove

bove another, which will be of length, about seven or eight miles, lying near upon S W, and N E; yet the *Cropps* of the said *Coals* (their *dipp*, and *rise*, being N W, and S E) are sometimes farder advanced towards the S E, sometimes farder back towards the N W, by the difference of a mile, and this generally occasioned by the encounter of a *Dyke* or *Gae*, whereof hereafter.

The same question, that occurred in the *Coals dipping* towards a Hill, or *rising* above ground, comes to be inquired into here; *viz.* If a *Coal* encountering an ascent, or *Brae* above ground in its *Streek*, rises also with the ground, and keeps its ascent? I answer, I have found it so in all the *Coals* I have ever seen of that nature. *GOD* in his providence, having so ordered it, that thereby it may be the more useful, in regard more thereof may be wrought by one *Level* or *Aquaduct*, by which the Water is conveyed away, as afterwards will be observed in speaking to *Levels*. For confirmation whereof, I shall bring instances both of *Coals*, that declines towards the Hill, and of others that declines with the same *dipp*, the Hill hath it self. In the *Coals* of *Bonhard*, *Grange*, *Kinglassy*, and *Kinneil*, which keep all one general *course*, the ascent above ground is from the Sea, (which lyes North) towards the South, or thereabout; the *Coal dipps* or declines towards the N W, and so consequently *rises* to the S E. The *Streek* of these *Coals*, is from the N E to S W, which slops alongs the Hill, and comes up to the top thereof to the Westward of the House of *Bonhard*. Now, in sinking in that ground, if an equal proportion be kept, in all the *Sinks* from the *Cropp*, and a just allowance given for the different *Rising* above ground, the *Sinks* will be near of an equal deepness along all the *Streek*. So that a *Sink* upon the

same

same *Coal* near to the Sea, which is the N E point of the *Streek*, at equal distance from the *Cropp*, will be as deep as a *Sink* upon the top of the Hill, being the S W point of the *Streek* at the same distance from the *Cropp*, allowing alwayes the different *rise* above ground, and excepting some particular *troubles* falling in upon the Metals of one *Sink*, and not of another, and so making them *dipp* more, which will occasion a difference of the deepness. The same is also found in the *Coals* of *Dysart*, and *Weems*. As also in that great body of *Coal* before mentioned, between *Preston-grange* and *Stobhill*, the declination whereof is to the N E, which is also the *course* of the descent above ground.

Another instance is from the *Coals* within the Lordship of *Tranent*, the *dipp* whereof is of another *course*, being contrary to the descent of the Hill, *viz.* the *Coal-dipping* to the S E, and consequently the *Streek* running S W, and N E, where the same is to be observed that was seen in the other, anent the equality of the deepness of *Sinks* along the *Streek*, with the same allowances, and exceptions before mentioned.

Some have been of opinion that *Streeks* of *Coals* ly generally South and North, or to some of the points near to these two Cardinal ones, between South and S W, and North and N E, as South and by West, and North and by East, *&c.* To which general I cannot agree, in regard of what I have before made evidently appear, *viz.* that some *Coals* have their *croppings* towards all the points of the Compass, and the *Streeks* being regulated by the *Cropps*, they must necessarily be judged to have their *courses* proportioned to theirs: so that if a *Coal dipp* to the true North, and *rise* to the *South*, the *Streek* must be East, and

West. However, I acknowledge two things, for confirming that opinion.

First, that of all the *Coals* I ever have seen, where these contrary *dipps* and *risings*, could not be traced, and made visible, the *Sreek* hath inclined to those points of South and North. But I must also confess, that they are but few I have seen, in respect of what I have not seen, and so if any others experience, who have seen more, contradict mine, I shall willingly yeeld, and not be tenacious.

Next, in these *Coals*, which I instanced, that have their *Cropp* to all the Points, and consequently their *Streeks*, and in others of the same nature, which I have seen, and not instanced, I found that part of the *Streek*, which lyes towards these *Cardinal points*, to be the greatest, being double, or triple to the other *Sreeks* in length. So that when the *Streek*, that lyes either along the one *Cropp*, or the other, towards the S W, and N E, will be seven miles in length, that lying S E, and N W, will be but four, and sometimes less. And this is all the account I can give, of that part of *Coal*, called the *Streek*.

The second thing I promised to speak of, was of some things, which are but accidental to *Coals*, and yet so ordinary, that hardly are any found without them in lesser, or greater degree, such are *Gae's*, and *Dykes*, which alters their natural *course*, and they being the occasion of so much *Trouble*, in the working of *Coal*, and following its *course*, the *Coal-hewers* call them ordinarily by that name *Trouble*. This *Trouble* or *Gae* then, is a Body of *Metal* falling in upon the *course* of the *Coal*, or *Free-stone*, obstructing, or altering their kindly and natural *course*, keeping no regular *course* it-self, and being of nature alwayes different from the Metal, whose *course* it interrupts. And these *Gae's* differ

fer alſo among themſelves, in their nature, and in their *courſe* they keep: or more properly in the way wherein they encounter other *Metalls*, and in their effects. In their nature, for ſome of them conſiſts of an impregnable *Whin-Rock*, or *Flinty-Stone*, thorow which it is almoſt impoſſible to work: and if there be a neceſſity to cut them thorow, it is done at a vaſt expence, and takes a long time, and muſt be cut open to the ſurface of the earth, it being impoſſible to Mine it under ground. Some of them are again of *Stone*, like a *Free-ſtone*, but ſeems rather an abortive of nature, they having no rule in their *courſe*, by which a man can follow them, nor can their ſtone be uſeful.

In their encountering of *Coals*, or *Free-ſtone*, ſometimes they encounter them in the *Dip*, and ſometimes in the *Streek*, and ſometimes between the two. Theſe that are met with in following the *Dipp* of the Coal, ly along the *Streek* thereof. For example, if the C*oal Dipp* S E, the *Gae* lies N E, and S W. Theſe that are encountered in the *Streek*, lyes to the *Dipp* and *Riſe*: ſo the C*oal Streeking* N E, and S W, the *Gae* is found to ly S E, and N W. Others of them, lyes between *Streek* and *Dipp*, that is to ſome point between the two: as the *Streek* being S W, and N E, and the *Dipp* and *Riſe* S E, and N W, there may be a *Gae* found lying W S W, and E N E. Now, when I ſpeak of a *Gae's* lying to ſuch Points of the Compaſs, this doth not contradict what was ſaid before, that they had no regular *courſe* themſelves. My meaning being, that though they have a certain length, lying between two points, and a thickneſs between two *Metalls*, yet by the *Metal* of the *Gae* it ſelf, it is impoſſible to know its *courſe*, as it is in other *Metalls* of C*oal* or *Free-ſtone*, whoſe *courſes* are diſcernable at the firſt view,

Their

Their effects are different, as their nature and *course* are different: only they agree in these two generals. First, that all of them renders that part of the *Coal*, that comes nearest to them, unprofitable and useless, though some less, and some more, they being unfit for burning. And it is remarked, that these *Gaes* that consists of *Whin-rock*, renders the *Coal* next to it, as if it were already burnt, being so dried, that it moulders in handling it. In others, the *Coal* is not altogether so ill, and yet its nature is altered, from what it is at a distance from the *Gae*. The next general is, that all of them alters the natural *course* of the *Coal* in less or more, some of them making it *Dipp* much more then its ordinary *course*, which they call *Down-gaes*: Some again making their *rise* much more than their *course*, which they call *Up-gaes*. Others making an alteration as to the *Streek*, causing it go out beyond its ordinary bounds, as we observed before in that great *Streek* of *Coal* between *Preston-Grange* and *Stobhill*.

Now it is to be considered, that when in working of a *Coal*, whether to the *Dipp*, or *Rise*, or *Streek*, one of these *Gaes* is encountered with, the *Coal* is quite cut off, and as it were *terminat*: so that you see nothing where the *Coal* should be, but either a *Stone*, or *Clay*, or rotten *Till*, or some such thing. And the practique of *Coallery* is to trace the *course* of the *Coal* through that, till you overtake it in the other side. And before any thing be said to that part, you must notice, that some *Gaes* are of greater force than others, and their influence upon the *course* of other Metalls greater, whence you shall see a threefold effect. One is, that by some great *Gaes*, which a *Coal* meets with, it is quite cut off, so that in the other side thereof, there is not a vestige of that *Coal*, or of any other Metal that was above

above it, or below it, to be seen. And if there be any other *Coal*, as sometimes there are, they are quite different from them of the other side. I said by *some*, because there is one instance to the contrary, which is somewhat singular. In the Earl of *Winton's* ground at *Cockeny*, there is found a *course* of *Coals* and *Free-stone*, *dipping* to the S E in the *Links*; and upon the *full-sea-mark*, there is a *tract* or *course* of *Whin-rocks* lying E and W, underneath which these *Coals* and *Stones* comes thorow without alteration of *course*, and are found within the *Sea-mark*, with the same *Dipp* and *Rise* upon the North side, they had upon the South side of the said *Rocks*: and yet the *Coal* is encountered upon the South hand by a *Gae* under ground, through which it passeth, not without a considerable alteration.

The greatest of these *Gaes*, that I know, is that which takes its beginning, that we see on Land, at the *Harbour* of the *Pans*, called *Achisons-Haven*, which hath been cut by *Preston-Grange*, for *Level* to his *Coal*, and goes from that to *Seton*, which may be traced above ground, almost the whole way; and hath been cut at *Seton*; for serving the *Level* of that *Coal* now wrought at *Tranent*. From thence it passeth through the fields of *Long-Niddry*, a place pertaining to the Earl of *Winton*, and through the *Coats*, which pertains to the Earl of *Hadington*, till it joyn with *Pancreck-hills*, a tract of Rocky Mountains, from whence it is traceable to *Linton-bridges*, where it is visible in the Water, the Water of *Tyn* falling over it, and making a *Lin*, which they call *Linton-Lin*; from thence to the *East-sea*. And it is known by Sea-men, that it keeps a *course* thorow the *Firth* from *Achisons-haven*, (whence we reckoned its beginning upon Land) towards the West

and

and N W, it being found to the Southward of *Inch-keith*, and before *Leith*, where ftands a *Beacon*, and fo can be traced to the North Shore.

The fecond effect of *Gaes*, is to cut off the *Coal* quite, as to a part of the field, fo that in the other fide, having pierced the *Gae*, you fhall not find the *Coal*, and poffibly not within a quarter of a mile of the *Gae*, which cuts it off, and at that place fhall only find the *Cropp* and the Body *Dipping*, as it did before it was cut off; and if you fhall meafure between that fide of the *Gae*, where you loft your *Coal* (I fuppofe the *Coal* then being 24 fathom from the *Grafs*) to the place where the *Coal* in the other fide of the *Gae* fhall be found at the fame deepnefs, it will be near 500 paces. For making this more intelligible, let us fuppofe a *Coal Dipping* S E, and in working to the *Dipp*, there is a *Gae* encountered with (This was really done in a piece of ground I know, and fo it is no meer fuppofition) at which *Gae* the *Coal* is cut off; for finding whereof the *Gae* is pierced, and nothing found in the other fide, *viz.* in the S E fide of the *Gae*, but at more than 100 paces diftant, the *Crop* of a *Coal*, which lyes under the *Coal*, that was loft, was found, after which it was eafie to find the other. Now, that it was the fame *Coal*, that was loft, upon the North fide of the *Gae*, is not only evident, by the kind of *Coal*, and all the *Metals* above, and below keeping the fame *courfe*, but by this, that the *Gae* wearing out towards the Weft, the two parts of the *Coal* that was feparated by it, joynes themfelves again, and continues in one body, as they were before feparation.

The laft effect of the *Gae* is, that it doth not quite cut off the *Coal* from the other fide of it, but makes an alteration in the *courfe*, either in the *Dipp*, or in the *Rife*, or

Streek,

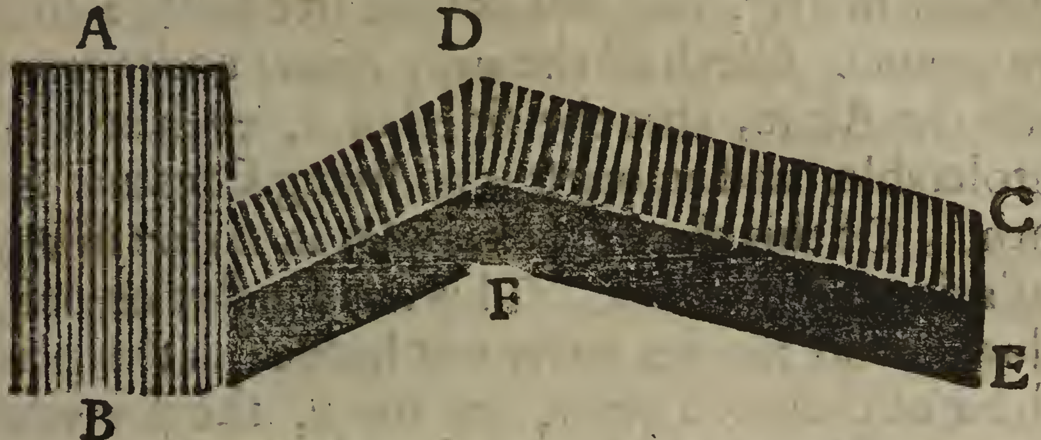
Streek, as was before noted: so that in meeting with one of these *Gaes*, having considered its nature, and pierced it, the Coal will be found in the other side, immediatly touching the *Gae*, but with an alteration of *course*. Now, in these two last effects, since the *Coal* is not totally cut off, it will be worth the inquiry, to find the surest way of recovering the *Coal* after it is lost. Therefore, where the *Coal* is not cut off, by a considerable distance, and having pierced the *Gae*, it is not to be found in the other side, you are to consider well the nature of the *Metals* you find approach to the *Gae*, and if they be such, whether *Stone*, or *Coal*, as you know to ly under the *Coal* that you have lost, then you may be sure the *Coal* is to be found above in its *course*, which is to be traced by the *Dipp* of the *Metals* you find. As sometimes I have seen, when a *Coal* hath been cut off by a *Gae*, happly there is another *Coal* under it 12 fathom, after the *Gae* hath been pierced, and the lost *Coal* not coming near to it in the other side, that hath been found there, by which it was certainly concluded, that the uppermost *Coal* behoved to be there also, though a little back, conform to its *course*. But, if the *Metals* or *Coals*, under the lost *Coal*, hath not been known, then you are to take notice of the *Dipp* and *Rise* of these *Metals*, you find on the other side of the *Gae*, which you have pierced, and making that your rule, *range back over the Metals*, conform to the direction to be given afterwards, and you shall find the *Cropp* of the *Coal* you want, and after which you were inquiring.

Where the *Coal* is not quite cut off by the *Gae*, but hath its *course* only altered, you are to consider, in searching for it, before you pierce your *Gae*, that which the *Coal-hewers* term the *Vise*, or some of them the *Weyse* of the *Gae*,

which in effect is nothing else, but a dark vestige of the *Dipp* or *Rise*, that the body which now constitutes the *Gae*, should have had naturally, if it had been perfected; which when it tends downward, then must the *Gae* be put over that way, and in the other side shall the *Coal* be found, and *Down*, as they term it; that is, the *Dipp* which it had naturally, augmented. And, if the *Rise* be *Up*, the same way must be taken for piercing the *Gae*; and the *Coal* will be found *Up*, that is, its *Rise* augmented. But these things cannot be made so intelligible, as by seeing, there being many things in the alteration of the *course* of Metals very curious, and worthy of Observation: as when a *Coal* is cast down out of its natural *course* by a *Gae*, and so made sometimes *under-Level*, it riseth as much to another hand, and the *Cropps* go so much farder out, which still makes the *Level* useful, the use whereof would have been judged lost by the *down-casting*. Sometimes a *Coal* made to have four contrary *courses*, as is evident from the eighth Figure, where there being a *Gae* at E, makes it take such another *course*, in stead of coming out to the *grass*. Sometimes, before the Metals overtake the *Gae*, they are made to ly like a *Bowe*; one instance whereof is visible above ground in some Metals lying between *Bruntiland* and *Kinghorn*, at a place called the *Miln-stone*, where there is a small *Coal* with *Free-stone* above it, all *Dipping* to the S E, and *Rising* to the N W. Upon the *Rise* they meet with a *gae*, which is a great *Whin-rock*. In their *course* to the *grass*, before they touch the said *Rock*, they take a contrary *course*, and *dipps* into it, and are there quite cut off. The manner whereof is to be seen in this tenth Figure following.

Figure

Figure 10.



Where A B is the *Rock*: E F the *Coal*: C D the *Free-stone*. Now, whereas they ſhould have riſen towards A, they turn at D, and *dipps* into the *Rock*, which any may obſerve in paſſing that way. Many other ſuch motions are obſervable, which I paſs, and leaves them to the obſervation of the curious.

The third thing I promiſed to ſpeak of, was of *Damps*, and as they are termed by the *Coal-hewers*, *Ill Air*. Theſe do deſerve a more accurat inquiry into their *kinds*, their *cauſes*, and *effects*; then I am capable to make, there being many things in them very conſiderable, and worthy of a narrow ſearch: therefore following the courſe I have hitherto obſerved, I ſhall ſhew my own Obſervations thereof, and leave the more curious ſearch to the ſpirits fitted for that purpoſe.

This *Damp* then makes an obſtruction of reſpiration in Men, or other living Creatures, in Subterraneous ſpaces, as *Caves*, *Coal-rooms*, *Levels*, *Sinks*, and ſuch like; which obſtruction proceeds principally from two cauſes, both which goes under the name of *Ill Air*, among the vulgar. The firſt is the corruption, or putrefaction of the Air, whereof there are two ſorts; one is in places where

hath been *fire* kindled, which burns the *Coal* under ground, the ſmoke whereof, being full of Sulphur, and other Bituminous matter, and not having free paſſage to come above ground, filleth all the *waſte Rooms* under ground, and infects the Air ſo, that the ſmell of it, even at a diſtance, is intolerable, and amongſt it no living Creature is able to breath. Of this there are examples in *Dyſert* in *Fife*, and *Fauſide* in *Eaſt Lothian.* This was kindled on deſign by a Fellow, who for his pains was hanged in the place, and hath burnt theſe 50 years, and more, the *fire* whereof is ſometimes ſeen near the *graſs*, with abundance of ſmoke, as it runs from one place to another. The ſecond, where the Air is corrupted without the mixture of ſmoke, or any other groſs corrupting body, which is the moſt conſiderable of all *Damps*, and hath the ſtrangeſt effects, in killing *Animals* in an inſtant, and ſo hath been alwayes moſt prejudicial in the works, where it is found, many perſons having thereby loſt their lives, without acceſs to cry but once *Gods mercy*, to ſome inſtances whereof I have been witneſs. I ſhall not offer to determine about the cauſe of this *Damp*, but ſhall give an account of ſomethings I have obſerved about it, which when duely pondered, may haply lay a foundation, at leaſt of a probable conjecture, whence it may proceed.

This kind of *Damp* then, and *Ill Air*, is never found in *Coal*, or other *Metals*, where there is Water to be found; I mean, whence the Water hath not been drawn away by a *Level*, or *Aqua-duct*: as in *Coals*, where there is a neceſſity to *lave* the Water from place to place, or to pump it along the aſcent or riſe of the *Coal*, to the bottom of the *Sink*, from which it is drawn out above ground, this *Ill Air* is not found. Nor is found frequently, if at all, in

theſe

these *Coals* where the Water is drawn from the *Coal* by a *Level*, or *Aquæ-duct* under ground, till it come of its own accord to the bottom of a *Sink*, which is in place of a *Ciſtern*, out of which it is forced alſo above ground, and differs only from the other, that the Water runs here of its own accord by a deſcent to the *Sink*, which is termed a *drawing Sink*: in the other it muſt be forced by the *Riſe* of the *Coal*, becauſe happly, a *Sink* upon the *Dipp* would be of ſuch a *deepneſs*, that no force could draw it up in a perpendicular.

But this kind of *Damp* is found ordinarily in theſe *Coals* from which the Water is drawn by a *Level*, the beginning or mouth whereof is above ground, and carried along by a right Line under ground, till it overtake the *Coal*, which it is to dry: ſo that the Water which comes from the *Coal*, runs without being forced, and is ſometimes ſo conſiderable, that it makes *Mills* go, without any other addition, as is to be ſeen in the Earl of *Wintons* Lands of *Seton*, where four *Mills* goes with the Water that comes from under ground, out of the *Coal*; which kind of *Levels* are only found where the *Coal* lyes in a Field, which hath a conſiderable *Riſe*, or aſcent above ground; there being a neceſſity to make uſe of the other two wayes ſpoken of, for drying the *Coal*, when the Field in which it lyes is a Plain.

Further, of theſe *Coals*, which are dryed by the *Free-level* (for ſo they term the *Level* that runs unforced) there are ſome to which this kind of *Damp* is more incident, than to others. The cauſe of which difference is found to be, the ſolidity and cloſneſs of the *Metals*, whether of *Coal* or *Stone*, wherein ſome exceeds another. There being ſome, that are full of *rifts*, or empty ſpaces (I mean

empty

empty of any part of the same body where they are) which will sometimes serve, to convey a considerable quantity of Water in place of an *aquæ-duct* or *level*; which *spaces* are termed by the vulgar, *Cutters*, which sometimes proves very profitable in the ground where they are found, both in regard of the use they serve for, in stead of *Level*, and for rendring the *Metals* wherein they are found, more easie to work, in making them yeeld easily to the force of the *wedge* and *leaver*. Other Metals there are, wherein few of these *Cutters* are to be found, and if water be to be conveyed through them, there is a necessity of cutting a passage through them for that effect. Now, this *Damp*, whereof we speak is found most frequently, and most violent in the first sort of *Metals*, *viz.* in these which are full of *Cutters* or *Rifts*, which gives some ground to this conjecture of its cause. These *Spaces* which are found in *Coal*, or other *Metals*, as *Stone* or *Till*, before the *Coal* begin to be dryed by a *Level*, are full of water, which is still in motion, as are all *subterraneous springs*, whereof some are more violent, some more slow, conform to the passage they have to the fountains above ground, where they discharge themselves. Now, for drying these *Coals*, and rendring them workable, there is a necessity to cut a passage, thorow which that water discharges it self quickly, it being large, and admitting a great quantity at once, by vertue whereof; a great field is drained at once, and the *Sourse* not being able to furnish so much water, as the *Conduit* is able to convey, these *Spaces* in the body of the *Metals*, being emptied of Water, must needs be filled with *Air*, which *Air* having little *contact* and *commerce*, with the great body of *Air* above ground, and so hath little or no motion, corrupts in these places, and thereby becomes

poisonable

poisonable, so that when any *Animal* is necessitat to draw it, and *respire* by it, it choaks them on a sudden, just as standing Water, which being without motion corrupts, and becomes poisonable, though haply not in so great a degree as the *Air*: the *Air*, being a body much finer and purer, than Water, that holding good in it, *corruptio optimi pessima*. This is much confirmed by what is before asserted, that in the *Coals*, whence the Water is drawn, and they drained, but not by *free-course*, but by *Force*, as *Pumping*, and drawing by *buckets*, these *Damps* are seldom or never found: because the passage of the Water being forced, it does not so suddenly dry the *Metals*, as the other, whereby there is alwayes left in these *Spaces* some Water, which being it self in motion, keeps the *Air* also in motion with it, and thereby the *Air* is kept from *corruption*, at least in such a degree, as it is in the other. Hence we find, that in these kinds of *Coals*, the *Rooms* under-ground are alwayes wet, or for the most part they are so: whereas in the other, there will be no Water found to wash a mans hands: and sometimes the *Coal* through want of Water, becomes so dry, that it cannot be wrought in great pieces, as others, but crushes in the very working, and when wrought, is rendered uselefs, and will not at all burn. This puts me in mind of a very pleasant conception of a worthy and learned Person, Doctor *George Hepburn* of *Monk-ridge*, with whom I had occasion one day to discourse on this Subject. He is of opinion that the *Water* is the *Mother* of the *Coal*, whereby it is preserved fresh, and incorrupted, and that when the *Water* is drawn off, and this *Damp* follows, it is not the *Air*, which succeeds in place of the *Water*, and is corrupted for want of motion, that occasions it. But as we see, when the corruption of a Li-

quor

quor within a Veſſel, when the *Mother* is gone, corrupts the Veſſel it ſelf, and occaſions an ill ſavour or taſte in the Veſſel; ſo that the *Coal* being corrupted by the want of its *Mother*, the *Water*; corrupts the Air in the ſubterraneous *Spaces*, as in *Coal-Mines*, *Sinks*, *Caves*, and other ſuch like. He had likewiſe another pleaſant conception about the *generation of Coal*, judging it to be formed gradually out of another Metal, as of *Till*, by the help of *Water*, of which he himſelf may perhaps give an account. And though I be not of his opinion in that matter, yet I muſt acknowledge, I was taken with it, and ſhall be glad to ſee a more full account of it from him, than he had acceſs to do in the ſhort conference we had.

The effects of this *Damp* are firſt, it hinders the burning of all combuſtible matter, as *Candle*, *Coal*, *Pitch*, *Sulphur*, &c. ſo that if you take a *Torch* lighted, and let it down to a *Sink*, where the *Ill Air* is prevalent in the time, it ſhall ſtraightway extinguiſh it. Or take a *Coal*, which is burning, and let it down, it ſhall not only extinguiſh the *Flame*, but ſhall make the *Coal* in an inſtant *dead*, and as cold as never heat had been in it. But the moſt dangerous effect is, its killing of *living Creatures*, whereby many perſons have been ſuddenly killed. Some in going down to a *Sink*, where it hath been powerful, have fallen out of the *Rope*, and periſhed. Others have been choaked, and yet have gotten out by the help of others in a ſudden, and have remained a conſiderable time without the leaſt appearance of life, but yet have at laſt recovered. Yet it hath been obſerved, that ſome of theſe perſons that have been ſo ſtruck with the *Damp*, and recovered, have had alwayes ſome *lightneſs of Brain* thereafter, and never ſo ſettled as formerly. This I know to have happened to one, whom I have ſeen ſo, many times thereafter.

What

What hath been its effects on some *Animals*, whereof you have made Experiment, I leave to the account you have given. One thing I shall only mention, which to me seems somewhat strange, that notwithstanding these *Damps* are so effectual, and causeth so suddenly the death of *Animals*, yet the *Ratts*, which are in some of these places, where the *Damps* are most violent, are not reached by them. For sometimes, when they are so powerful, that nothing that lives can enter under ground, without sudden death, yet they continue there, and are not found to diminish, even where they have no access to escape, by coming above ground. Or if it should be imagined, they removed to some other place of the ground, where the *Damp* is not, how is it, they are not as quickly choaked with it, as *Dogs* are, and other *Animals*, which at the first encounter are killed?

If it be inquired, how comes it to pass, that in these Fields of *Coals*, which are dryed fully (as was said) and to which these *Damps* are incident, because of corrupted Air that remains within the Body of the *Coal*, or other *Metals*, how comes it to pass (I say) that they are but sometimes incident, and are not alwayes found? For clearing this, it is certain, that even in the grounds, where these *Damps* are most frequent, for the reasons above-mentioned, yet they are only powerful when the Wind blows from such a certain *Point*, as some Chimneys, that do only smoke, when the Wind is in such an *Airth*. This is so generally, and well known, that the *Work-men* observe it, and when they find the Wind in such a Point, whence they fear the *Damp*, they will not enter under ground, till trial be made of the Air, which they do in *Sinks*, by first let-

ting down a lighted *Candle*, or some burning *Coals*: which if they do not burn, then there is no access to enter.

Secondly, the Wind in which this *Ill Air* is most noxious, and hurtful, blows from that Point, where the Field of *Coal* lyes, that's not yet wrought, which seems somewhat strange, and yet when duely considered, it will appear abundantly consonant to reason. An example of this is to be found in the *Coal* of *Tranent* and *Elphingston*, the *Streek* whereof goes to the *rise* of the Hill above ground, from N E to S W, as hath been formerly observed. So that the beginning of their *Level*, is at the N E point of the *Streek*, from which the *Coal* hath been wrought up along the *Streek* towards the S W, the *Wastes* lying all towards the N E. Yet when the Wind blows from N E, or N, or almost from any other Point of the Compass, they are not troubled with this *Damp*. But if it blow from S W, and blow hard, they are in hazard to encounter it. And though the *Damp* is not alwayes found when that Wind blows (whereof there may be some particular cause) yet it is never observed in another Wind, whether it blow less or more: the reason whereof may probably be, that the Wind blowing from other Points, as from N, or N E, hath more access to enter the *Wastes* under ground, and move the Air that is in them, towards the face of the unwrought *Coal*, whence is supposed to proceed the corrupted Air, that lurks in the *Rifts* and *Cutters* thereof, (from which the Water is drawn away,) and occasions the *Damp*. Now this Air being moved by the force of the Wind, keeps the corrupt Air from coming out, it being stronger then the other. Whereas, upon the contrary, while the Wind blows from S W, it entering the empty *Rooms*, drives the Air under ground from the face of the un-

wrought

wrought *Coal*, down towards the *old wastes*, which have their *course* from the beginning of the *Level*. By which means, the Air, that is corrupted within the bowels (to speak so) of the *Coal*, comes out to the *Wastes*, without resistance, it being certain, that *Fluid Bodies*, as *Water*, and *Air*, inclines to move towards that place, where they meet with the least resistance. Hence is it, that the more direct the Wind be, in blowing against the face of the unwrought *Coal*, as is the Wind from N E, the *Ill Air* is the more repelled and driven back, but the more oblique it be, as are the Winds from these Points, that are nearest to S W, the *Air* is not so good and free: which difference is known by the burning of *Candles*, they burning with greater difficulty in these Winds, than in others, which blow from these Points nearest to N, and N E. Some are of opinion, this *Ill Air* (in those places we have been speaking of) comes from the great *Wastes*, that ly above the un-wrought *Coal*, and by strong S W Winds is driven thorow the *Cutters* thereof. Or the Wind blowing from that Point, and coming thorow these *Cutters*, brings the corrupted Air alongs with it, even as, after a showr of Rain, a spait of Water comes, and carries alongs with it, both the foul Water and the clean, it meets with. Though this may be probable, which seems to be your own opinion, yet the other seems to be more probable.

The other sort of *Damp*, is that which they call *want of Air*; and though the term be not altogether proper (there being no space without some Air) yet there is a want of Air, which is sufficient for respiration of *Animals*, or for the burning of fire. This is ordinarily found in the running of *Mines* under ground, for conveying of Water from *Coal*, or other *Metals*, or in the *waste Rooms* of *Coals*, where

the *Sinks* are very deep, and to evite the charge thereof, there is some necessity to work as far under ground for winning of *Coal*, as is possible, without new *Sinks*. The cause seems to be, that the Air under ground, in such cases, wants communication with the Air above ground, because it is found, that by giving more communication, the evil is cured. Whence comes the necessity of *Air-holes* in *Levels*, which are so many *Sinks* set down, for no other use, but for giving Air to the *Workers*. Some are of opinion, that this defect might be supplied by the blowing of Bellows, from above ground, through a Stroop of Leather, or of some other thing, which must run along to the end of the *Level*, for keeping the Air there in motion. But I have not yet heard, that it hath been made practicable.

The effects of this *Damp* are not so dangerous, as these of the other. 'Tis true, it will kill Animals, and extinguish burning *Coals* and *Candles*, but not so suddenly as the former; and so people are not so readily surprized by it. The other seems to kill by some poisonous quality: in this *Animals* dies for want of sufficient Air for respiration. Therefore in advancing in a *Coal Room*, or *Level* where this is, you shall see the flame of the Candle grow less and less by degrees, till at last it be totally extinguished, and the person entering, shall find the difficulty of breathing grow greater, as he advanceth forward, till at last he cannot breath at all. Hence it is, that few or none are killed by this kind of *Damp*, and all its prejudice is, that it renders the work more chargeable, when there is a necessity to remove it.

For that, which they call *Wild-fire*, it being a thing not incident, but to very few *Coals*, is less known, than any of the rest of the accidents that follows *Coals*. The account

count I have heard of it, is, that in some *Coals*, which naturally are full of *Oil*, and that are (as they call them) *fatt Coals*, there is a certain *Fire*, which is as a *Meteor*, and I judge, that from its resemblance to *Ignis fatuus*, which the Vulgar termeth *Wild-fire*, it hath the same name. It seems to be composed of some *fatt oily vapour*, that goeth out of the *Coal*, the *Pores* thereof being once opened, which is kindled after the same manner, as those fires above ground are, which are most ordinarily found in fatt, and marrish ground. Of this fire it is reported, that in the day time, while the *Work men*, are working in the *Coal-roomes*, it comes to no height, though it be sometimes seen in little holes of the *Coal-wall*, shining like kindled sulphure, but without force: but when the *Work-men* are once removed, and have stayed out all night, it gathers to such a strength, that at its first encountering with fire, which the *Coal-hewers* are necessitate to have, by taking in of light, it breaks out with such a violence, that it kills any person, it finds in its way. The reason, why it is without this force, while the *Work-men* are in the place, seems to be this, that they working with such violence, and motion as they do, do certainly move the Air considerably, it being contained in so narrow a place, as a *Coal-room*. And this Air being violented by motion, moves that *oily vapour*, whereof the fire is formed, so that it gets not liberty to unit it self, being dissipated by the motion of the Air. But so soon, as the Air is still, and quiet, after the *Work-men* are gone home, it units it self, and gathers force, and therefore, so soon, as it meets with fire, which is more forcible, than the flame that is kindled in it, it rarifieth; the sulphurious parts being kindled, and forceth it self out, as powder out of a *Gun*. For it hath been observed, that if any person stay in the *Coal-*

sink

ſink while it breaks within the *Coal-room*, they are in danger of being killed. The ordinary way by which the hurt of it is prevented, is by a perſon that enters, before the *Work-men*, who being covered with *wet ſack-cloath*, when he comes near the *Coal-wall*, where the *Fire* is feared, he creepeth on his belly, with a long *Poll* before him, with a lighted candle on the end thereof, with whoſe flame the *Wild-fire* meeting, breaketh with violence, and running alongs the *roof*, goeth out with a noiſe, at the mouth of the *Sink*, the perſon that gave fire, having eſcaped, by creeping on the ground, and keeping his face cloſe to it, till it be over-paſſed, which is in a moment.

The place, where this was moſt known, was in a *Coal* be-weſt *Leith*, in a piece of Land called *Werdy*, which for want of *Level*, and the violence of that *Fire*, the *Owners* were forced to abandon.

I come now to the laſt part, which I promiſed to ſpeak of, namely of the beſt way for trying of grounds, to find *Coal*, where never any hath hitherto been diſcovered, and of carrying on of *Levels*, for draining the Water of *Coals* and making it workable. As to the firſt part, there are but three wayes. Firſt by *ſinking*, which is moſt chargeable, in regard, that in ſuch grounds, where the *Metals* are all intire, Water abounds, and this doth not only bring the *Maſter* under a neceſſity of great expence for drawing the Water, but alſo rendereth it impoſſible to get *ſinked* to any deepneſs, which may ſuffice, for giving an account of all the *Metals* to be found, within the field, that may be rendred workable. There was a ſecond way invented to ſupply this defect, which is by *boaring*, with an inſtrument made of ſeveral *Rods* of Iron, which boareth thorow the *Metals*, and tryes them. This way in my opinion, is

woſe

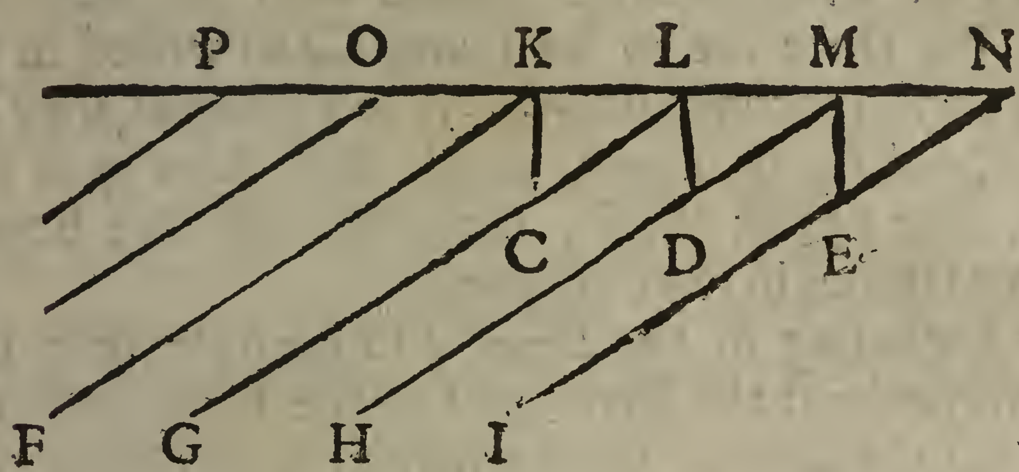
worse then the former. For first, if the *Coal* ly deep, in the place where you try by boaring, it becomes almost as tedious, and expensive, as *sinking*, the drawing of the *Rodes*, consuming so much time, in regard it must be frequently done. Next, in *boaring*, suppose the nature of the *Metals*, be found, yet thereby their *course* can never be known, till they be *sinked*, which is one of the things most considerable in the search of a *Coal*, because thereby is known, whether it be workable, with advantage or not, and whether it be possible to draw Water from it by a *Level*, or otherwise. Lastly, this way leaves the *Master* at an uncertainty (notwithstanding the *Coal* had been found) of its *goodness*, as to its *nature*, and as to its *thickness*. As to its *goodness*, because all that is found of the *Coal*, by this *boaring instrument*, is some small *dross*, which remains after the washing of the thing that's brought up in the *wumble*, by which none can judge of its *goodness*, or *badness*. As to its *thickness*, because it is impossible to discern exactly, when the *boaring-instrument* hath passed the *Coal*: all the rule for trying thereof, being the kind of *Metal* that is brought up in the *wumble*. Now, I have known in my experience a *Coal boared*, which the *Boarer* by that rule hath judged four foot in *thickness*, yet when it came to be *sinked*, hath not proven one. The reason whereof, is obvious, because the *boaring-irons*, being long, and weighty in lifting them up, and down, they break the *Coal*, already pierced; and this falling down among the *Metals*, they are piercing, and being found in the *wumble* with them (especially when the *Metal* under the *Coal*, is a *black Till*) gives ground to imagine, that all that time, they have been peircing a *Coal*, and so consequently, the *Coal* must be of such a *thickness*.

The

The last, and best way of trial, is that which is termed an *ranging over the Metals*. For doing whereof, this method, is to be observed. Suppose there be any place within the ground to be searched, where the course of *Metals* can be seen, as in the *banks* of a *River*, or *Rivolet*, or *Sea-banks*, when the place is near the Sea, then consideration must be had how far the lowest of these *Metals*, can go before they C*rop* out to the *Grass*, which will be known by observing the *Dipp* or declination of the *Metals*, and the *Rise* of the ground above, whereof a just allowance must be given, and having *digged* before the said *Crop*, you shall certainly find, the *Metal*, that is next under it, and if that prove not C*oal*, keeping the former proportion, you must advance, and *digg* before its C*rop*, and so shall you find, the next *Metal* under it, and so still, till you have tried your ground, and found the *Crops* of all your *Metals* within it. But if there be no *Water-banks*, or such like, to give you the first view, of the course of your *Metals*, then must you *sink* first at *random*, and having once past the C*lay*, you will readily overtake some *Metals*, whereby you will know the *course* of the rest, and having once found the *Dipp* and *Rise*, you must follow the method of *ranging* already prescribed, except the ground so to be tried, contains not within it self the C*rops* of the *Metals*, the body whereof lies in it, whether of C*oal*, or *Stone*, in that case, there is no way to try, but by *sinking*, or *boaring*. The way of *ranging* is conspicuous in the following figure.

Figure

Figure 11.



The piece of ground to be tried, is P N, where there are several *Seams* of *Metals*, that *Cropps* out at the Points K L M N. Suppose the lowest to be the C*oal*, *viz.* I N, for which you are to make trial. You *Digg* first at K, without the *Cropp* of the *Seam* F K, and you *dig* till you find the other *Seam* of *Stone* G L, at the Point C. Following the Rule before given, you advance before its *cropp*, and *diggs* at L, and finds the other *Seam* of *Stone* H M, at the point D: from which you also advance, and *diggs* before its *cropp*, at the point M, and finds your C*oal* at the point E. But, if by advancing over the *cropps* of these *Metals*, which comes out from under one another, you find no C*oal*; then you are to *range* backward, for the *cropps* of *Metals* lying above these, where haply the C*oal* may be, as at O, and P. This in my opinion, is the most certain and exact way of trying Fields for C*oal*, or any other *Metal* of that nature, and least chargeable of all others.

The second of this last part, I promised to speak of, was in order to *Levels*, or C*oal-Mines*, which are nothing else, but C*onduits* or *Gutters* made under ground, for conveying of the Water from the C*oal*, and so rendering it

workable. It feems that a very little time before this, that way of *Mineing* under ground hath not been fallen upon. For there are to be found Coals wafted in their Cropps only; for conveying the Water whereof, they have made a *Conduit*, or *Level*, which hath been *open to the Surface*, like a great *Ditch*, fome whereof have been ten or twelve fathom in their deepnefs.

The beginning of the *Level* (to keep the term ufed) muft alwayes be at the loweft part of the Field, where the Coal lyes to be dryed. Some whereof, by the *rifing* of the ground, and the *Streek* of the Coal rifing that way (as we fhew before) gives the advantage of a *Free Level*, that is, when the Water comes above ground of its own accord, without being forced by drawing. In others, there is a neceffity of *Engines* to draw the Water from the loweft part of the *Level*, and bring it above ground; which *Engines* are of feveral forts. As when *men draw* with ordinary *Buckets*, or when there is a *horfe-work*, or *water-work*, and that either by a Chain with *Plates*, and a *Pump*, or with a Chain and *Buckets*; all which are very common, efpecially thofe we have in *Scotland*, they being capable to draw but a very fmall draught, making only ufe of one *Sink* for that effect. But there are to be feen in the North of *England*, in *Bifhoprick*, *Water-works*, by which Water is drawn above 40 fathom in perpendicular, but not all in one *Sink*. The manner whereof is thus, there being a *Sink* from the end of their *Level*, to the furface of the earth, where their *Works* are going, 40 fathom deep, which muft dry the *Coal-Sinks* at 60 or 70, which ly above the *Banks* of the *River*, where the *Water-works* are fcituated, there is firft one 40 fathom deep from the *Grafs*. Another in a right Line from that, of 24. Another of 12; upon all which there

there are *Water-works*. In the firſt *Sink* the Water is drawn from the bottom 12 fathom, and thence conveyed into a *Level* or *Mine*, which carries it away to the ſecond *Sink*. By the ſecond *Work*, the Water is drawn out of the ſecond *Sink* 14 fathom, from the bottom, and ſet in by a *Level* to the third *Sink*, which being only 12 fathom deep, the *Water-work* ſets it above ground. The form of the *Engine* is after this manner. In the firſt *Sink* there is an *Outter-wheel* moved, as other *Milns* are, by the Water of the River: upon the end of the *Axle-tree* of which *Wheel*, there is a *Ragg-wheel*, turning *vertically*, as doth the *Outer-wheel*. This *Ragg-wheel* by a *Nutt*, or *Trinle* turns another, which moves *horizontally*, the *Axle-tree* whereof goes right down in the *Sink*, and may be is 8 or 10 fathom; at the end whereof there is another *Ragg*, which by a *Nutt* turns another *Wheel*, which goes *vertically* as the firſt *Ragg*, and cauſeth another Wheel with a long *Axle-tree* turn as the firſt, and ſo down till it come to the *Wheel*, which turns the *Axle-tree*, by which the *Chain* is drawn. The ſecond *Sink*, hath ſuch another *Engine*, but not ſo many *Wheels*, in regard it is not ſo deep. The third, hath only one *ſingle Wheel*, whereby the Water is drawn above ground.

The moſt curious of theſe *Engines*, that are to be ſeen, are at *Ravenſworth* near to *Newcaſtle*, which belongs to Sir *Thomas Liddel*, a moſt ingenious Gentleman, who, for procuring a *Fall* of Water, which may ſerve the *Wheels* of all the three *Sinks*, hath erected the firſt work upon Pillars like a *Wind-Mill*, pretty high above ground, from which the Water falling, makes the ſecond go cloſs above ground. And to make the Water fall to the third, the whole *Wheel* is made go within the *ſurface* of the ground, which *terminats* at a *River* under the *Works*, which *Mine*

is of a considerable length. Where Water cannot be had to make such *Works* go, they use *Horse-works*, but not with so good success, being more chargeable, and not having so much force and power, as the *Water-works*. But I am of opinion, that *Wind-works* might serve well, where Water cannot be had; and when no Wind should happen to blow, the same *Works* might be supplied by *Horse*: and that the *Wind*, when it blows but ordinarily, hath as much force, as so much Water, which is made use of for turning such *Wheels*, is to me unquestionable. For I have seen in *Holland*, a *Wind-Mill*, that by the motion of the *Outter-wheel*, caused seven pair of *Mill-stones* to go at once, besides another motion for bringing the *Victual* from the ground, four or five Stories high, to be *Grund*. And several *Saw-Mills*, which besides six or seven great *Saws*, they caused go, did by another motion bring up from the *Water* great *Trees* like *Ship-Masts*, to be *sawen*, and placed them right against the *Saw*; all which could not be but of greater weight, than 10 or 12 fathom of *Chain* with *Buckets*, or *Plates* for drawing of Water.

But to return, for the right making of a *Level*, the true hight of the ground, where the *Coal* lyes must be first taken, that it may be known, how much of the field can be drained by it; which must be done, either with a *Quadrant*, or with an Instrument made expres. Then care must be taken, to take the lowest part for the mouth of the *Level*, that the field can afford, and from that it must be carried in a straight line towards that part of the field, where the *Coal* is thought to be encountered by the *Mine*. In working whereof, two things are in a special manner to be reguarded. First, that the *Level* be wrought without *ascent*, or *descent*: the best way for trying this, being by the surface

face of the Water passing through it, which ought to be as little moving, as can be: for the loss of one foot of *Level*, which the ground gives, is a loss of a considerable parcel of *Coal* to be digged, especially if it be *flate*. If there occur any *Metals*, which are impregnable, in the *course* of the *Level*, so that it is impossible, to follow so straight a line, in regard the *Mine* must be wrought over the top of that stone, which is unworkable, in that case, there is but one of two to serve the loss of *Level*; either the Coal rises in *Streek* towards which the *Mine* is carried, and if that be, then after that *stone* is past, the *Level* must be carried, as low, as it was before it encountered the same, and the *course* of the Water shall not be obstructed, because the *sourse*, viz. the *Coal* from whence the Water comes, rising higher than the *Stone*, the Water shall easily pass over that hight. Hence it is, that we see in some *Coals*, that have been wrought, at the lowest point of their *Streek* by a *drawing-sink*, and the *Streek* rising from that point, the Water that hath come off the *Coal*, being in its *Sourse* higher, than the mouth of that *drawing-sink*, hath made it to over-run, and serve to discharge all the Water, that comes therefrom. But, if the *Mine* be run to a *Coal*, that after it hath overtaken it, rises no higher in *Streek*, than the *Mine* it self, the Water that comes from it, will not pass over any hight in its way, but will be unquestionably stopped. Therefore, in case such an impediment could not be removed, as many times such *Metals* will fall in, which are unworkable in a direct line, the use of a *Siphon* might be tried, which would unquestionably supply the loss of about 32 foot of *Level*, this being the hight in Perpendicular, to which the *Pressure* of the *Air*, is able to raise Water up thorow a *Siphon*.

The

The next thing to be observed in carrying on of *Levels*, are the *Air-holes*, for which there is a necessity indispensable. In setting down whereof, care must be had, that they be not directly upon the *Mine*, lest *rubbish* falling thorow from above ground, should stop, and obstruct the same, and so obstruct the *course* of the Water; and therefore it's better they be set down at a *side*, their only use being to communicate fresh Air to the *Work-men*, which if it could be otherwise supplied (as I think it not utterly impossible) would render the charge of the *Coal-works* a great deal more easy.

Other things might be spoken to of *Levels*, as that some run with the *course* of *Metals*, they pass thorow; and that some run against that *course*; and of bringing *Level* from the *Dip* of an *upper-Coal*, which hath a *Level* of its own, to dry a *Coal* lying under it, which cannot be otherwise done. But these things being common and obvious to any, who have but the smallest skill and experience, I shall forbear.

This confused account, your importunity hath drawen from me, for which if your *Book* suffer censure, which I grant it may do, as to this part of it, you are to blame your self, and so I rest and am, *&c.*

FINIS.

POSTSCRIPT.

Reader,

THat thou mayeſt know the riſe, and occaſion of this Poſtſcript, which I have ſubjoyned, I ſhall give thee this ſhort account. When this Book was firſt committed to the Preſs, I ſent an intimation thereof to ſeveral perſons, whom I judged would encourage it, yet to none, but to ſuch, in whoſe kindneſs I had confidence, and whom I judged my real friends. Among others, I ſent over to Saint *Andrews* one of my Edicts, to one or two there, in whom I truſted, but in ſtead of a kindly return from them, to whom I had written moſt affectionatly, they wrot back a Letter, wherein they ſuperciliouſly condemn the purpoſes of this Book, before ever they had ſeen them, which is as follows.

Sir,

I *Received yours on* Saturday *laſt, and having occaſion the ſame night to be in company with many of the Maſters of the Univerſity, I made known your reſolution to them, ſhewing them your Edict, and deſiring their Contributions: ſome were not pleaſed, that ye call the Doctrine concerning the weight and preſſure of the Water in its own Element, new, ſeing* Archimedes *hath affirmed, and demonſtrated in his Books* de inſidentibus humido *the ſame Geometrically 2000 years ago; others affirmed that it was ſo far from being new, that they would undertake to demonſtrat the event of any of all yonr Experiments à* priore *from* Archimedes *his grounds, yea, in general of any Hydroſtatical Experiment, ſeing they look upon it,* as a Science long ago perfected. *Some ſaid, as to Diving, that they imagined any method better then that of* Melgims, *which is now vulgar, to be impoſſible. As to the Obſervation of the Sun, or Moons motion in a ſecond*

 of

of time, yea, or much leſs, it can be done moſt exactly by a Teleſcope, and a Pendulum, but ſerves to no purpoſe, ſeing that ſame motion can be had infinitly more exact by proportion, from obſervations of a conſiderable interval; for ſo the Aſtronomers collect all the middle motions of the Planets. As for the Obſervations of Coal-ſinks, latitude of Edinburgh, *and its variation of the Needle, they may aſſuredly increaſe the Hiſtorical part of Learning: yet many of the Maſters here imagine themſelves concerned in credit not to promote the publication of any thing, which ſeemeth to declare our Nation ignorant (by calling them new, and unheard of) of theſe things known over all the World theſe many years among really Learned Men, albeit they be debated amongſt ridiculous Monkiſh Philoſophers. I conceive, ye would do beſt to undeceive this Univerſity, by ſending us ſome of your moſt abſtruſe Theorems, and ſurprizing Experiments; which if they be not evidently and clearly deduceable from* Archimedes, *or* Stevinus, *who did write long ago, or rather, if they be not the ſame with theirs: ye may aſſure your ſelf that this Univerſity will take away at leaſt all the obligations ye have ſent here; otherwayes, I am afraid, I ſhall not be able to prevail with them. I hope ye will pardon this my freedom I uſe with you, and return an anſwer with the firſt occaſion, to*

St. *Andrews, December.* 27. 1671.

Sir,
Your moſt humble Servant.

After the receit of this, being unwilling to make it a ground of debate, I returned a moſt diſcreet anſwer, thinking to conquer their humour with civility, and kindneſs, but not long after, hearing of their clamour againſt the Intimation, and of their diſſwading others, who would willingly (I ſuppoſe) have condeſcended, I was neceſſitated to ſend this return, for a joynt anſwer to them both, for beſides this, another of the ſame kind came alſo, of which hereafter.

Sir,

Sir,

I *Received yours, of the Date of* December 27. 1671. *and though it was a little unpleasant, yet I took it very kindly from you, as from a person I judged ingenuous, as my return of* January 9. 1672. *can witness, wherein I did not in the least resent any thing you wrot; neither would I ever have done, if you, and some others especially with you, had not proclaimed publickly, what you and they had written to me privatly, the noise whereof, I have heard here, by several persons who came from the place. Therefore, Sir, you must pardon me, if now at last, after so much silence, I return you this answer, for no other end, but for my own vindication, in what I have lately Printed, and am about to Print. I am very much then surprized with the answer, that you and they have returned, such a rank smell of prejudice and envy, I find in it. I am rewarded evil for good; for I minded nothing but good-will; else, you and they should never have been troubled with my proposal. If they had affected the reputation of Learning, there was another way to it, then the course they have taken, namely to condemn with such a deal of superciliousness, as derogatory to the credit of the Nation; forsooth, the labours of one, that hath done more for the credit thereof, then they have done as yet. They might have minded the saying of the grave Historian,* Nam famam atque gloriam, Bonus atque ignavus æque sibi exoptant: ille verâ viâ nititur, huic, quia Bonæ artes desunt, dolis atque fallaciis contendit. *And for undeceiving of the University, as I am very far from counting such persons the University, so have I more respect for it, and all Learned Persons in it, then to account their deed, the deed of the University. As for what they can do, for promitting the work I have now at the Press, I value it not at the rate of shewing them so much as one of my Theorems: for, if they have snarled so much, as but at one word, in the intimation of the work; what would they do, if they had more of it? which yet must stand firm, unless they (for 'tis a matter of fact, and cannot be contradicted with* Sophistry *and* Non-sense) *overthrow it, which I little fear, as* Cicero *did* Verres, Tabulis & Testibus ad singula indicia prolatis. *Neither will their imagination do it, for that cannot make* factum infe-

ctum. *It seemeth to be a great weight, that they lay upon the force of their imagination, since they are so confident, as to say, they imagine any method of* Diving *better then that of* Melgims, *to be impossible*, adeo familiare est hominibus supra vires humanas credere, quicquid supra illorum captum sit. *As for these others, that would demonstrat* à priori, *the event of all my Experiments from the grounds of* Archimedes, *as I doubt not, but they would, if they could, so in this they bewray their want of skill: for* Archimedes *wanted a necessary* requisite, *which I go upon for my deductions. And though it were true (which they say) that all my* Theorems *were demonstrable* à priori *from the grounds of* Archimedes, *yet this doth not hinder them to be both new, and un-heard-of, as if new, and un-heard-of conclusions, might not be deduced from old principles. In this they are so much the better, and not the worse. And whereas they say, they look upon the* Hydrostaticks, *as a Science long since perfected, in this they do yet more discover their* weakness: *for what one Science hath yet come to its perfection? Nay, hath not this* Pedantick *humour been the great* bane *of good Learning, that Sciences were already perfected? So that* Seneca *said truly*, Puto multos pervenire potuisse ad sapientiam, nisi putassent se pervenisse. *As for the representing of the* Sun *or* Moons *motion* to the eye *(for that should surely have been taken in) that you say, serveth to no purpose, to me is a little uncouth, considering how much it conduceth to the accuracy of Astronomical Observations, beyond what the former Ages could attain to. And whereas you say, it can be had infinitly more exactly by Observations of a considerable interval, as Astronomers collect all the middle motions of the Planets, but I say, even those intervals should have been far better known, if they had by this mean, and the* Oscillatory Clock *been observed; so whatever arguing by the rule of proportion, may do for shewing the* Suns *motion in* seconds, *and* thirds, *it reacheth not these accuracies, that are reached by this invention, so long as the* Sense *cannot deprehend, and fix them. As for the Observations of* Coal-sinks, *&c. which you say, may assuredly increase the Historical part of Learning; are they not for this the more useful, since the Scientifical part of Learning dependeth so much on the Historical part, and which conduceth more thereto, then all the pre-*

carious principles of Cartesius, Epicurus, *and the like; who in stead of giving us an account of the World that* God *made, have given us imaginary ones of their own making: so that such a History, as* Natural Philosophy *requires, is wisely accounted among the* desiderata *in Learning by all sound Philosophers to this day. So much in answer to yours, and I rest*

Edinburgh, Feb. 22. 1672.

Your Servant.

IN answer to this last, there came to my hands from *St. Andrews* a Letter unsubscribed by any Master, full of barbarous railings, passing all bounds of civility, against my self, friends, and works, which, if the *Contrivers* had not been more gall'd with reason, then injuries, I suppose they would have forborn. And thinking this not sufficient, they would needs aggravate the wrong, by one circumstance more, which they either did out of *disdain*, or *fear*, not daring to own what they had contrived, in making the *Bedale* of the University subscribe it. And to give a further proof of their insatiable malice, they must needs distribute copies thereof, as glorying in their shame, one whereof was sent over to *Edinburgh* unsubscribed also. Now, let any indifferent person judge, whether or not, I have not reason to do what I have done. They have been the first proclaimers, though in a *clandestine* way, and why not I next, in this way. But lest, they think, they have marred as much the tranquillity of my mind therewith, as they have their own, I shall answer in the words of the Moralist, *Eleganter Demetrius noster solet dicere, eodem loco sibi esse voces imperitorum, quo ventre redditos crepitus. Quid enim inquit, mea refert, sursum isti, sive deorsum sonent.* And let this stand, for the railing part of the letter.

But first, whereas he should have spoken to the contents of this Book, he falleth foul upon my last Peice, intituled, *Ars nova, & magna, gravitatis, & levitatis*, snarling eight or nine times, at the bare title, like a *Cur* at the horse heels, when he cannot reach the rider. This lay not in his way, doing herein like *Vejento* the blind

Courtier of *Domitian*, who, when he should have turned his face to the right hand, where the *Sturgeon* lay, turned it to the left.

——— Nam plurima dixit
In lævam conversus: at illi dextra jacebat
Bellua.

So that concerning all these *invectives*, I may say, *sed quid hæc ad Rhombum.* But what other can be expected, *ubi furor arma ministrat.* But seing his Letter shews, how sick he is of the plague of malice, and envy, I am so far from storming at him, that I pity him, though he may be a Master, and teacher of others, and wish him to teach himself. *——Servitium acre*

Te nihil impellit ? nec quicquam extrinsecus intrat
Quod nervos agitet ? Sed si intus & jecore ægro
Nascantur domini, quî tu impunitior exis
Atque hic, quem ad strigiles scutica & metus egit herilis.

That I do not interpret this (Reader) excuse me, for I am speaking (I suppose) to a Master of an University, and a gentleman too, of very high pretences, as to learning. And yet I cannot but think strange of two things. First, that he returneth not the least *Latine* sentence in answer to mine, no not so much as pertinent language in his *Mother-tongue.* What ? An University-man, and no return in *Latine* to these sayings, of so grave Authors, or at least in pertinent English. The other, that he no more understands, these words, *as Cicero did Verres, tabulis & testibus ad singula indicia prolatis*, than the *Curat* did the *Modicum bonum* that he was desired to prepare for the Bishops dinner. For, whereas he saith, *as for your Latine sentences, where ar our doli, and fallaciæ, tabulæ & testes, sapientia ad quam putamus nos pervenisse.* To pass the first and last question, of which anone, the second was most improper for him to ask at me, who did put him to it, to overthrow the title of my Experiments, to wit *New*, not by *Sophistry*, and *Non-sense*, but as *Cicero* did *Verres*, *tabulis & testibus*, by proof and Witnesses ; this he should not have asked, but answered. I am confident a Boy in the *second* Class, could better have understood these words, than this man. And for the first question, *where are our* doli, *and* fallaciæ ? Why should he ask it,

seing

ſeing the deſign of his Letter may be evidently ſeen, to put *Royal Societies*, and *Univerſities* between him and me, in the front, whom I have not made my party, but to whom I owe all due reſpect, and ſuch a poor pitiful fellow as the *Bedale* in the *Rear*, in cauſing him ſubſcribe his letter thus,

March 14. 1672. *Mr.* Patrick Mathers, *Arch-bedale to the Univerſity of* St. Andrews.

Is not this to do, as the *Butcher* did, who ſought his knife, when it was ſticking in his teeth. If the Univerſity ordered this ſubſcription, it would have been ſaid, *at the command of the Univerſity.* If not, it cannot be purged from a falſe inſinuation: and the Univerſity may juſtly reſent it, that their publick ſervant, hath been ſo abuſed. If the fear of a counterblow hath made him afraid, to put his hand to it, he hath done as the *Ape* did, that thruſt the *Cats* foot into the fire, becauſe he durſt not do it himſelf, and given a palpable diſcovery of the diffidence he had of his cauſe. If he hath done it, to put indignity on his adverſary, he hath miſſed his mark, for as a certain Writer ſaith well, *Infamy is as it is received. If thou be Mud-wall it will ſtick: if Marble it will rebound: if thou ſtorm at it, it is thine: if thou deſpiſe it* (as I do this) *it is his.* But beſides this, he endeavoureth to put Mr. *James Gregory* between him and me alſo, and bringeth him in ſpeaking of my writings, with ſuch a deal of diſdain and ſaucineſs, *ut nihil ſupra.* What? was Mr. *James Gregory* ſuch an eminent perſon, that he could not ſpeak his thoughts himſelf, but needeth you Sir, for a *Proxy*, and Chancellour to ſpeak for him. If Mr. *James Gregory* will ſpeak to me, what you have ſpoken in his name, he ſhall have an anſwer. But I have no mind to gratify ſo far your *doli*, and *fallaciæ*, as to fall on any man upon your word, having ſo little confidence of your common honeſty. This were *perverſam gratiam gratificari.* Wherefore paſſing his impertinent railings, I come to anſwer, what he hath returned to my purpoſes in my laſt. And that he may get no wrong, I ſhall ſet down the very words of his Letter, *viz.*; *as to what you write concerning the imperfections of Sciences: the Scientifical pairt of Geographie is ſo perfected, that there is nothing re-*

quired for the projection, description, and situation of a place, which cannot be done, and demonstrat. The truth is they have overshot themselves in this, though they be ashamed to acknowledge so much; for what a pitiful shift is it, to bring *Geography* for an instance of a perfected Science, when so much of the Earth remains to this day unknown altogether, as the *Universal Mapps* testify. Of the known parts, how little is there to this day sufficiently described by the exactest *Mapps*, that time, and labours of men have yet produced. And now to retort your own question upon your self, *ubi est sapientia ad quam putatis vos pervenisse?* O but saith the Author, *it is perfected as to its scientifical part.* But I pray you *Sir*, what is this, though you may be a teacher of *Logick* of no small esteem with your self, and disdain of others, but to play the *Sophister*, by the *Fallacy*, *à dicto secundum quid, ad dictum simpliciter*: *Geography is perfected as to its scientifical part, therefore it may be called a perfected Science*, when it is so defective as to the *Historical part.* If *Astronomy* to this day be a Science not perfected, through want of its *Historical part*, shall not *Geography* be so likewise. But furder *Sir*, for the *Scientifical part* of *Geography*, which you alledge to be perfected, in this also you argue against the rules of *Logick*, in committing that same *Fallacy* over again, for giving and not granting what you say, that the *Scientifical part of Geography* were perfected, as to the *projection, description, and situation* of a place, is it for this perfected as to the *Scientifical part simpliciter*, which you are obliged to prove, else you say nothing to the purpose. And what I pray you, is that poor alleadgence you make, in comparison of these things, wherein *Geography* is defective, even as to the *Scientifical part?* Who hath spoken yet sufficiently to the *surface*, and hight of the *Sea* above the *Earth*, the hight of the *Hills*, and *Mountains*, *Longitude* of places, nay the circumference of the Earth it self? Answer this question, if you can, *Hast thou perceived the breadth of the earth, declare if thou knowest it all?* Job. 38. 18. And now Sir, I must put you to it again, *ubi est sapientia ad quam putatis vos perverisse.*

His next answer runneth thus, *The Scientifical part of the Opticks is so perfected, that nothing can be required for the perfection of the*

ſight, which is not demonſtrat, albeit mens hands cannot reach it. And theſe being the objects, of the foreſaid Sciences (you ſhould *Sir*, have ſaid, the whole objects of the foreſaid Sciences, elſe you ſtill play the Sophiſter) *your authority ſhall not perſwade him, or us, that it is altogether improper to call them perfect.* But mark Reader, how the force of reaſon maketh theſe *Authors* to ſuccumb: for whereas they ſhould have ſaid, *that it is not improper to call them perfect*, they qualify it thus, it is not *altogether* improper. And again, *your authority ſhall not perſwade us, that it is altogether improper.* But (*my Maſters*) I do not crave that my authority may perſwade you, but reaſon. Wherefore to return: *the Scientifical part of the Opticks* (ſay they) *is ſo perfected, that nothing can be required for the perfection of the ſight, which is not demonſtrat, albeit mens hands cannot reach it.* But where *Sir*, and by what perſon is this done? Shew me the man, (if you can) that hath done it. But though all this were true, were therefore, either the *Opticks, Dioptricks, or Catoptricks* perfected Sciences? Who hath yet ſufficiently explained the manner *how we ſee*, far leſs how *Birds*, and *Fiſhes*, *Beaſts*, and *Inſects* ſee? How the *Eagle* mounting aloft ſpyeth her prey from a far. Who hath ſpoken ſufficiently to the nature of *colours*? For theſe alſo belong to the *Opticks*, or of *light*, and of the *infraction*, and *refraction* thereof. The learned *Lord Verulam* was not of your mind *Sir*, when he wrot thus, *De forma lucis, quod non debita ~~non~~ facta fuerit inquiſitio (præſertim cum in Perſpectivâ ſtrenuè elaborûnt homines) ſtupenda quædam negligentia cenſeri poſſit. Etenim, nec in perſpectivâ, nec aliàs, aliquid de luce, quod valeat, inquiſitum eſt.*

If Mr. *Newton* had been of this *Authors* mind, he ſhould not have attempted the late invention of his *Span-long Dioptrical-catoptrical Proſpect*, whereby *Jupiter* his *Satellites*, and *Venus horned* are to be ſeen. And if Mr. *Hook*, had been of his mind, he ſhould not have made his late *Propoſal* of *Teleſcopes*, *Microſcopes*, *Scotoſcopes*, by figures as eaſily made, as thoſe that are plain and ſpherical, whereby the *light*, and *Magnitude* of *Objects*, may be prodigiouſly increaſed, and whatſoever elſe hath hitherto been attempted, or almoſt deſired in *Dioptricks*, may be accompliſhed. Where ob-

ſerve (Reader) how that ingenuous perſon, is ſo far from the *windy language* of this Author, that he doth not ſay, *whatſoever can be required for the perfection of ſight is demonſtrat*, or any thing like it, but *whatſoever hath been hitherto attempted, or almoſt deſired.* For who can tell, what ſhall be found out hereafter, even in theſe things. To them we may borrow the words of the Poet,

Prudens futuri temporis exitum
Caliginoſâ nocte premit Deus.

So, Sir, I ſtill put you to that queſtion, *Ubi eſt ſapientia ad quam putatis vos perveniſſe ?*

In the next place he falleth upon the *Hydroſtaticks*, which formerly he looked upon as a Science perfected long ago. But becauſe in his anſwer, he in effect yeelds the cauſe, I purſue him no further. *Habemus confitentem reum*, while he expreſly grants, *there are many things yet* (ſaith he) *relating to the proportion and acceleration of the motion of Fluids , which are yet unknown.* As for his reflections upon what I have written in my *Ars Nova*, concerning a perpetual motion, which I never intended to demonſtrat, I leave them as *indicia ægri & impotentis animi.* I proceed to anſwer him in what he addeth thus. *Only we cannot but admire your ſimplicity in this, Aſtronomy ſeeketh alwayes to have the greateſt intervalls betwix obſervations , and ye take that ye will give an excellent way for obſerving the Sun or Moons motion for a ſecond of time, that is to ſay, as if it wer a great matter, that there is but a ſecond of tym betwix your obſervations. I wonder yow ſay the eye ſhuld be added, for the invention had been much greater had that been away.* But what is this Sir, but ſtill to play the *Sophiſter* ? Is not this the *Sophiſm, ab ignoratione Elenchi* ? for it doth not contradict my concluſion, which is, that Aſtronomical Obſervations, by this mean, and the Oſcillatory Clock, may be made to a ſecond of time, which is of ſo great importance in *Aſtronomy*. But mark the *Non-ſenſe* (Reader) *the invention* (ſaith he) *had been much greater, if the eye had been away* : that is, the invention of this Obſervation had been much greater, if the *eye*, that is, the *obſervation* had been away. In this they have outſhot themſelves alſo ; and what they ſpoke

unadviſedly

unadviſedly before, they will now ſpeak deliberatly, and defend it rather by *Sophiſtry* and *Non-ſenſe*, then yeeld to the truth.

Has toties optata exegit gloria pœnas.

The Author addeth, *None will denay but that an guid hiſtory of nature is abſolutelie the moſt neceſſary requiſite thing for learning, yet it is not like, that yow are fit for that purpoſe, who ſo fermelie beleeves the myrakles of the Veſt, as to put them in Prent, and recordeth the ſemple Meridian Altitudes of Comets, and that only to halfs of degrees, or little maire, as worthy noticing.* If it were needful, I could produce the paſſages of ſome of the moſt Learned Writers, of theſe laſt times, that have recorded the like. Were they therefore unfit to write Hiſtory? A perſon of this Authors reading and learning, will ſoon find them out. If he do it not, let him know, that I keep them for a *reſerve.* To ſpeak nothing of *Ariſtotle,* who wrot a Book περὶ θαυμασίων ἀκουσμάτων, extant to this day: was he therefore unfit to write his *Natural Hiſtories?* Prodigious relations, when the memory of them may be found credible, and maintainable, ſuch as mine are, ought not to be excluded from a *Natural Hiſtory,* or elſe the Learned Lord *Verulam* is much miſtaken in the third *Aphoriſm* of his *preparatory to Natural and Experimental Hiſtory.* Nor had he reaſon to carp at my Obſervations of the *Comets,* as long as he made none himſelf. But they will ſpeak for themſelves to any that read them. Neither need they him for a *Common Cryer,* either to commend them, or diſcommend them; who, when I was at theſe Obſervations, he poſſibly hath not been ſo well exerciſed.

He ſubjoyneth, *However if yow do this laſt part concerning Colſinks weill, and all the reſt be but an* Ars Magna & Nova: *ye may come to gaine the repute of being more fit to be an Collier, than a Skollar.* I muſt tell this *Pedant,* that a *Coal-hewer* is a more uſeful perſon in his own ſtation, to the Countrey, than he is; and that the Science of *Coal,* and other *Minerals,* is far beyond any knowledge this man hath, or can teach. But, my *Lords* and *Gentlemen,* who are *Coal-Maſters,* mark this: if ye ſtand to the judgement of this *Pedant,* though ye had never ſo much skill in theſe things, ye may come to gain the repute of being more fit to be

Coal-hewers, than *Schollars*; as if the knowledge of ſuch things were not a part of *Natural Philoſophy*. It ſeems he hath either forgotten the common *definition*, or elſe hath never known it, that *Phyſica eſt Scientia Corporis Naturalis*.

He ſubjoyneth, *Ye might have let alane the precarious principles, and imaginary Worlds of* Deſcartes, *till yowr new inventions had made them ſo: for it man be telled yow* Deſcartes, *valued the Hiſtory of Nature, as much as any experimental Philoſopher ever did, and perfected it more with judicious Experiments, than ye would do by all appearance in ten ages*. But I pray you, Sir, did *Des-cartes*, and *Epicurus*, and the like, found their *Philoſophy* on *Natural Hiſtory*, and not rather upon their own *precarious principles*: and therefore have quite miſſed the mark, and method, that was requiſite for the advancement of Learning, and have been ſo far from *graſping* Nature, that it hath *flowen* out from among their hands. As for what he talketh of *Des-cartes*, perfecting *Natural Hiſtory* by *Experiments*, if he had done it, as the Poet ſaith in another ſenſe,

Non mihi res, ſed me rebus componere conor.

he had done right. But when he took pains on theſe, to force them to a compliance with his own *fancies*, was not this to ſtudy *Natural Hiſtory*, as *Hereticks* do the *Scripture*, and to be a *Fanatick Philoſopher*, and a fit Maſter for the like of you. The *Proteus of Nature*, muſt be bound with ſtronger Chains, then the *fantaſtick Nugæ of Des-cartes*, before he will tell his ſecrets. The vanity of whoſe method may be ſeen in the *Epicureans*, who having laid down this precarious principle, that *the ſenſe cannot erre*, do turn themſelves into ſo many ſhapes, to prove *that the Sun is no bigger than a blew Bonnet*.

In end, after he hath given a *Fling* at my labours in *Glaſgow Colledge*, about *Univerſale*, and *Ens rationis*, which I am not afraid he ſhall come the length of in haſte, for ought I can learn, he falleth foul upon the two Lines I cited out of *Juvenal*, in the cloſe of my anſwer to a paſſage in a *Philoſophical Tranſaction*: the Lines are,

——*Cujus ſapientià monſtrat*
Summos poſſe viros, magnaque exempla daturos
Vervecum in patriâ craſſoque ſub aëre naſci.

Of theſe Lines, he writeth thus, *Of which* (ſaith he) *the ſenſe is not underſtood, except ye make your ſelf the* ſummus vir, *and us all* Verveces. *I ſuppoſe this may be the great credit, that ye ſay, ye have laboured to gain to your Nation,* viz. *to get us all the honourable Title of Weathers.* But (Reader) had theſe *Learned Clerks* been as skilful in *Rhetorical Compoſition*, and *Reſolution*, as in *Algebraical*, they would not have made ſuch an *Inference*: for the Argument is *à minori ad majus*. Nor was it ever intended for another end. As for the *honourable Title of Wedders*, which they alledge I have gained to them, I cannot indeed affirm it; for if I ſhould, ſome ſurely would judge me to have wronged them as much in this, as I have done them right all alongs.

But, that thou mayeſt know (Reader) ſomething more of the temper of thoſe perſons I have to do with in this matter, take but the following words of one of them, as they are tranſcribed out of a Letter written with his own hand to me, after I had written to him a friendly Letter for obtaining the concurrance of his acquaintance for advancing my Book, *And they promiſe* (to wit the Maſters promiſe) *ye ſhall not want their concurrence, whereof ye may be ſure, eſpecially having here your friend* Mr. Gregory, *your Couſin, and me here to put them in mind. This is all at preſent, from, Sir, your real friend and ſervant.*

Now, what ſhall be thought of one, who will ſpeak ſo fair to your face, and yet cut you with ſo many invectives behind backs, let any man judge.

Aſtutam vapido ſervat ſub pectore vulpem
—— *Hic niger eſt, hunc tu Roman- caveto.*

But to give a further diſcovery of him, in the year 1661, a certain ingenious Gentleman, that had not been bred a Schollar, by his own induſtry advanced ſo far in the *Mathematicks*, that he was able to ſet forth an *Almanack*, for which, ingenuous and ingenious men ſhould have commended him. But this *Author*, with another, though he had never injured them, and without advertiſement, fell

upon him like a couple of *Mastives*, upon a harmless Passenger, as if they would have *worried* him in his reputation, in a *Prognostication* they set forth, rateing and abusing him out of measure: all the cause being some alledged mistakes, they thought they found in some of his calculations, and in a Table in the end of the *Almanack*, which he calleth *perpetual*, and which they say, though falsly, that it will not hold. What had that *righteous man* deserved at their hands, to be so abused in Print by them? But that the design is palpable, *the raising of reputation to themselves, upon the ruine of the names of others?* And yet one of them many years after, was necessitat, for fear of *bodily harm*, to crave him pardon, *with humble offer to his knee.* In the *Prognostication*, he would needs play the *Poet* in his *Chronology*, which the person whom he wronged, might have found more fault with, with better reason, than he could do with him, for his Calculations. What a stranger he is to the more polished part of Learning, for all his high pretences, these Verses will abundantly testify, some whereof follow, that thou mayest know the rest, *Tanquam ex ungue leonem.*

Since that the *Julian* period first began.
Since that of nought the Lord created man.

He should have said,

Since that of dust the Lord created man.

He addeth,

Since *Israel* from *Egypt* Land did flee.
Since in *Canaan*, he made *Hams* sons to die.
Since *Romulus* did build his stately *Roma*.
Since *Nabonassar*, hence is that ancient *æra*.
Since *Gregory* helped the Calendar forlorn, *&c.*

Mark Reader: these Verses are of five feet, at least they should be so: but how far he is from observing the Precept of that great Master of Poets,

Primum ne medio, medium ne discrepet imo.

Will appear from his close,

Since fair *Lucina* fulfilled the Golden Number.
Since glistering *Phœbus* augmented Sundays Letter.

Euge Poeta.

It may be he will ſay, every man is not born to be a Poet. I anſwer, If the Gentleman, whom he reviled, failed in a calculation, he ought to have been born with, and encouraged: for there are many things that even a mediocrity is commendable in; but Poeſie is none of theſe.

——— *Mediocribus eſſe Poetis*
Non Dii, non homines, non conceſſere Columnæ.

However, for this, he may aſſure himſelf, that

Perque Poetarum nunquam celebrabere faſtos.

But I leave him to the *Satyriſts* of the time, *Quo illuſtrius vapulet*, for his never being ſeen farder in Print, than by a railing *Almanack*, and ridiculous *Verſes*, the better whereof, might have been made by the Laird of *Dyſert*.

'Tis like this Antagoniſt, will ſet his *Plumbeous Cerebroſity* a work to rifle ſome of my Writings, and ſhake his head, when he is put to a *demur*, as ever a man did a bottle for *Sack*; but though he ſhould, and I have nothing of his, but an old *Prognoſtication* of the Year, 1661, to ripe up, yet who knowes, but I may meet with ſome of his *Bajan-notes*, or ſome of his wonders about *Ens Rationis*, and *Genus Logicæ*, that he is now ſweating at. I am indeed at ſome diſadvantage, while he only letteth a *fliſk* at me, from under deck. Though I have been a little ſnell in this reply, yet 'tis no wonder, conſidering what a barbarous, and uncivil *Piſſle* I met with, which I ſhall keep for a reſerve. I deſire to live peaceably with all men. Neither ſhall I be ſoon provocked, ſo long as they keep within the bounds of civility. If that be obſerved, I ſhall thank them, for any miſtake they ſhall let me ſee in my writings, if done with reaſon, and without railing.

FINIS.

John Tulbory his Book
Bathgate Ap 2th 178